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A CENTURY OF WOOD PRESERVING



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A CENTURY OF WOOD PRESERVING

EDITED BY

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(First President of the British Wood Preserving Association)



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PREFACE

IT IS ABOUT ONE HUNDRED YEARS since Mr. Bethell first concerned himself with the creosoting of timber, and as I am about completing my fiftieth year of occupation in the creosoting industry and have therefore been so occupied for half the time of its existence as an industry, I am glad to take the opportunity of making a few remarks introductory to this publication.

My attention has been strongly turned recently to the very small meed of fame accorded to John Bethell, and it is a fortunate coincidence that something like a centenary celebration of his embarking on his great discovery should occur by the foundation now of a British Wood Preserving Association, in the archives of which his memory is sure of being enshrined for ever. Posterity, I think, will accord him a place in the Temple of Fame as important as that accorded to his brother, the Lord Chancellor.

The present compilation I dedicate to the British Wood Preserving Association, of which I have the great honour of being the first President.

In 1853 Mr. H. P. Burt, who had succeeded to the business of Mr. Bethell, read a Paper to the Institution of Civil Engineers on the subject of "Wood Preservation." One had been read previously by Mr. Bethell. In 1884, about midway in what I may call the century of wood preserving, a Paper was read at the Institution of Civil Engineers by my father, then Mr. S. B. Boulton, who had succeeded Mr. Bethell and Mr. Burt as head of the first

creosoting business ever established. This Paper obtained the Telford Gold Medal of the Institution.

I have made a summary of the matter contained therein, by permission of the Institution of Civil Engineers, and for fuller details must refer readers to the official Proceedings of that body or to the original publication, a few copies of which are still available. I was present at the reading of the Paper and at the subsequent discussions which occupied two evenings, and of course took a great deal of personal interest in the proceedings and in the experiments in connection with the Paper.

I am fortunate in being able to secure the services of Mr. Hubert Fergusson, of Burt, Boulton & Haywood, Limited, whose technical qualifications are far above my own, to supplement my father's Paper by a summary, both historical and scientific, of subsequent developments in the industry up to the present date. Mr. Fergusson's experience very nearly bridges the period between 1884, when my father's Paper was read, and the present time. It is hoped that the volume thus put together, while not pretending to be either a technically scientific manual or a complete historical work, will be of use, not only to those interested in the subject either as suppliers or consumers of treated timber, but to a much wider circle to whom the subject of Wood Preservation will appeal on scientific or national grounds.

SUMMARY OF
"THE ANTISEPTIC TREATMENT OF TIMBER"

A Paper read before the Institution of Civil Engineers
in 1884, and subsequent discussions

BY

SAMUEL BAGSTER BOULTON
(Assoc. Member Inst. C.I.)

THE ANTISEPTIC TREATMENT OF TIMBER

THE PAPER begins with a reference to the one read by the Author's late partner, Mr. Burt, in 1853 (6), (20).¹

There follow various interesting and instructive particulars of early wood preservation by the Greeks and Romans and references to the ingredients used, such as the "astringent portions of the oil expressed from olives (*amurca*) (16), (70), also oils derived from the cedar, the larch, the juniper, and the nard-bush (*Valeriana*) (70), (71)," and a reference to what Herodotus (41) and Pliny (72), (73) had to say as to wood preservation. Interesting particulars are given about the treatment employed in preserving Egyptian mummies (42), (35), (57), (65), (33), (66), (77), (69), (67), (68). The conclusion arrived at is that "the immunity from decay was not due to a chemical transformation produced once for all, but that it depended upon the abiding presence of the antiseptic. In recent anatomical practice, carbolic acid has been used for injecting bodies for purposes of dissection. When this is done, however, it is found necessary to renew the process after the lapse of a few weeks, a contrast to the antiseptics employed by the Egyptians (92). Pettigrew's description showed that the worst preserved of the mummies are those prepared with natrum alone, the most perfect being those in which solid resins or bitumens remain incorporated."

"The Author has caused some experiments to be made

¹ NOTE.—The numbers in parentheses refer to various authorities, Appendix F.

with pieces of timber, in order to test a theory which suggested itself to his mind. The wood was first thoroughly impregnated with a mixed solution of the three salts of sodium of which the natrum brine is composed. Afterwards the wood was steeped in tar oil heated to 230° Fahrenheit. The heat of the tar oil volatilized the water of the soda solution, and the oil took the place of the water. The timber remained impregnated with the saline particles, and saturated with the tar oil. May not this have been the method used by the Egyptians to impregnate both with natrum and oils? ” “ The ancients were of opinion that those woods lasted the longest which were most odoriferous or, in other words, those which contained the greatest quantity of resin (74). They knew that timber continually kept under water was less liable to decay than when exposed to the atmosphere (75). They observed the ravages of the *Teredo navalis* upon timber placed in the sea (76).”

*Growth of Theories upon the Causes of
Putrefaction*

The Author goes on to say that it is not until the eighteenth century that any serious analytical research into the causes of decomposition was undertaken. The researches of Scheele, Priestley, McBride and Sir John Pringle are quoted (37 and 38) :

“ Little by little the similarity of the natural processes connected with the fermentation of alimentary substances, the decay of vegetable tissues, and the putrefaction of the bodies of animals began to be recognized,”

but the Author states that many of the substances put forward as preservatives, particularly the alkaline bodies, are absolutely injurious to timber. Attempts to preserve the wooden ships of the British Navy are mentioned (39) and various metallic salts were suggested, but the substance actually used does not appear certain. In this connection the names of Sir Humphry Davy and Thomas Wade (39) are mentioned.

“From the year 1768 up to the present time, the records of the Patent Office contain lists of almost every conceivable antiseptic, suitable or unsuitable, for the preservation of wood.”

Progress During the Railway Era

It appears that by the year 1838 various systems of antiseptic treatment were on trial, viz. :

“Corrosive sublimate, introduced by J. H. Kyan ; sulphate of copper, by Mr. J. J. Lloyd Margary ; chloride of zinc, by Sir William Burnett ; heavy oil of tar (afterwards called creosote), by Mr. John Bethell.”

CORROSIVE SUBLIMATE. Two Frenchmen, Homberg and De Boissieu, one of the early and the other of the late eighteenth century, and the Dutch Government of 1730 (58), (36) are mentioned in connection with corrosive sublimate, and Kyan's first patent, taken out in 1832 (43). Sir Humphry Davy is mentioned as recommending it (39). We are told that the process was for a long time the most popular for dry land, but that the British Admiralty and Dutch Government had found it fail in sea water, a defect which it shares with all the metallic salts.

SULPHATE OF COPPER. In connection with this the

names of De Boissieu and Bordenave in 1769 (59) and Thomas Wade in 1815 (39), and of Mr. Margary in 1837 (48) are mentioned.

CHLORIDE OF ZINC. Chloride of zinc was recommended by Thomas Wade in 1815 (39) and Dr. Boucherie in 1837 (60), the patent in this country being taken out by Sir William Burnett in 1838 (9). "The process of Burnettizing was at one time much patronized by the British Admiralty. For railway sleepers it was extensively adopted in France by the Author's firm, principally on the railways from Orleans to Bordeaux and from Caen to Cherbourg." "Chloride of zinc is a powerful antiseptic, but its weak point for wood preserving consists in its extreme solubility in water."

Heavy Oils of Tar Commonly Called Creosote

Among men and methods mentioned before the advent of Mr. John Bethell's patent in 1838 (3) we find Franz Moll, 1836 (49), who had a method "for injecting wood in closed iron vessels with the oils of coal-tar first in a state of vapour and next with the heated oils in the ordinary liquid state." He appears to have been the inventor of the word "creosote," which was sometimes spelled "kreosot" and sometimes "creasote." Of course, in either case the word is simply a compound of two Greek words meaning the preservation of flesh or fibre. Moll recommended that his operation should be begun with injection of oils lighter than water, called "eupion," followed by the injection of heavier oils which he called "kreosot." Apparently this plan was abandoned as unpractical and wasteful, owing to the evaporation of the lighter oils in the process.

It is pointed out that Mr. Bethell's patent of 1838 (3) does not mention the word "creosote," though "it contains a list of no less than eighteen various substances, mixtures or solutions, oleaginous, bituminous, and of metallic salts. Amongst them is mentioned a mixture consisting of coal-tar thinned with from one-third to one-half of its quantity of dead oil distilled from coal-tar. This is the origin of the so-called creosoting process." A reference is made to Dr. Tidy's *Handbook of Chemistry* (95), not only as to scientific conclusions arrived at, but as to verbal confusions which arose between experiments on coal-tar creosote, wood creosote and carbolic acid.

In addition to the four processes already mentioned, Mr. Charles Payne is mentioned as having taken out a patent in 1846 (64) for "the injection into timber, first of a solution of a sulphuret of barium or calcium, and next of a solution of sulphate of iron, the object being to form an insoluble sulphuret in the pores of the wood." This process is criticized as a failure.

Liebig's Theory of Eremacausis

Liebig's Theory of Eremacausis next occupies the attention of the Author, which he describes as a theory "that the processes of fermentation in certain fluids, and of the putrefaction or decay of organized bodies, animal and vegetable, were caused by a species of slow combustion." "That it required for its ordinary development the presence of moisture and of atmospheric air; that its action was provoked by oxygen, and that its method of action was by a communication of motion from the atoms of the infecting ferment to the atoms of the body infected. He denied that fermentation, putrefaction and

decomposition were caused by fungi, animalcules, parasites or infusoria, although these organisms might sometimes be present during the processes."

"But he also stated that the phenomena of decomposition might be suspended by extreme heat or cold, that they were accelerated by the action of alkalies, and retarded by that of acids, and that they might be arrested by the use of certain antiseptics (47)." He also states that Liebig, "enlarging upon the views of previous investigators, had proclaimed the identity in composition of the animal and vegetable albumens" (47).

"It was proclaimed (although probably not by Liebig) that the coagulation of the albumen was the true specific against decay of wood. Corrosive sublimate, sulphate of copper, and chloride of zinc, and the tar oils were all powerful agents for that purpose. It was claimed for all four of these processes that they coagulated the albumen contained in the wood, and that they formed insoluble compounds therein, thus arresting decay."

On the practical side it appears that the creosoting process began to prove the most suitable and reliable. The late survival of the sulphate of copper process in France under the Boucherie process is then mentioned, and followed by reference to the writings of two French chemists, Payen (61) and Maxime Paulet (62), which no doubt helped to lead to its practical extinction.

Marine Timbers

With regard to marine timbers the conclusions of the French, Dutch and Belgian Governments are noted (13), (24), (23 and 40), and cases of both success and failure subsequently alluded to.

Origin and Properties of the Tar Oils

The Author of the Paper describes in some detail the origin and process of manufacture, and gives various diagrams illustrating what is known as the destructive distillation of coal-tar, the originals of which are not here reproduced but replaced by others kindly prepared by the staff of Messrs. Burt, Boulton & Haywood, Limited (Plates 1, 2 and 3).

It is remarked that "the temperature during the distillation ranges from 180° to 758° Fahrenheit" (he was speaking in 1884), and that "the main object of this distillation is to break up the tar into three groups of products, viz. oils lighter than water (crude naphthas); oils heavier than water; pitch, the residuum of distillation, which last product is run out from the bottom of the still, and solidifies upon cooling into a hard black substance. It is in connection with the component parts of the two groups of oils, and their separate and subsequent treatment, that some of the best known and most brilliant discoveries of modern industrial chemistry have been developed (25), (27), (29). The oils lighter than water, however, have no part in the preservation of timber. It is not uncommon to hear inquiries as to whether the discovery of the aniline dyes has not, somehow or other, interfered with the quality of the creosoting liquor. There exists a singular and unfounded prejudice on this subject. The materials for the aniline dyes are not, and never have been, taken from the creosoting liquor or heavy oils; they are taken exclusively from the oils lighter than water, which last have never been employed for the creosoting process, and are valueless for timber preserving. The benzol, toluol, etc., from which the aniline dyes are produced, are extremely volatile, like alcohol."

He notes that formerly the whole mass of heavy oils of tar was used for timber preservation. A detailed account is given of the modifications introduced into various specifications by engineers and others. He goes on to say that :

“ It has been seen that Mr. Bethell's original patent recommended the use of the mother liquor, or coal-tar, thinned with a portion of heavy coal-tar oil. So late as 1849, Bethell's licences for the use of his patent described the process as ‘ saturating timber with the oils obtained by the distillation of gas-tar, either alone or mixed with gas-tar.’ The Author remembers how, in the early days of creosoting, inspectors frequently refused to allow the thinner and lighter dead oils to be used without being thickened with tar. Tar, the mother liquor, necessarily included all the substances contained in the dead oils, plus the naphthas and the pitch. The reasons for not adopting the tar in its entirety are simply that the crude naphthas are useless as antiseptics, and would immediately evaporate, whilst the pitch, from its too great solidity, would form an impediment to the injection. The dead oils, therefore, came into use alone, and there crept into some of the specifications the contradictory prescriptions that the wood was to be creosoted according to Bethell's patent, but that the creosote was to be free from adulteration with coal-tar.”

“ As regards the question of thick or thin oils, there is no doubt as to the opinion and practice of the earlier introducers of the creosoting process. In January, 1853, Mr. Bethell stated that ‘ the product of Newcastle coal contained a quantity of naphthalene, and that he was an advocate for its use ’ (4). In November, 1864, he said that ‘ the creosoting process was not, as often described, a chemical process entirely ’ ; that creosote did coagulate

albumen in the sap of the wood ; ' but that was not his only idea when he introduced the process ; his object was to fill the pores of the wood with a bituminous, asphaltic substance, which rendered it waterproof, &c.' " (5).

With regard to the question of the coagulation of the albumen being a vital part of the process of creosoting, it will be noted that both in the Paper and subsequent discussions a good deal occurred to shake the accuracy of this theory.

Reference is then made to the large quantities of Baltic sleepers creosoted in this country and despatched to India. Papers by Mr. Bryce McMaster read in 1859 and 1863 are quoted (21), as also a Report by Mr. Juland Danvers in 1863. The kind of creosote used for these early Indian sleepers was mainly at first the heavy so-called London oil, i.e. oil produced from the distillation of coal-tar obtained from Newcastle coal (7 and 8). " The quantity of creosote injected into these sleepers was at first from 35 to 40 gallons to the load of 50 cubic feet, as compared with the 50 and 60 gallons of the present day." The Author remarks that a great deal of the creosote formerly shipped in the sleepers to India would, in 1884, have been rejected. A reference to Mr. Fergusson's Paper later on in this volume shows the important evolution which has taken place in creosoting specifications since that date.

Mention is made of the great preference in earlier days for thinner oils, partly accounted for by the fact that Inspectors and those who had to deal with the sleepers preferred the look of those impregnated with thin oil, and partly because a great deal of the creosote manufactured outside London was of a lighter specific gravity, and, most important of all from a scientific point of view, was the growing predilection of chemists for the idea that carbolic

acid¹ was the most important agent of wood preservation, a theory which is combated both in the Paper and the subsequent discussions, and to which nothing like so great importance is attached in present day specifications as in former times.

The work of Lunge, a German chemist, in 1834 and publications by Dr. Letheby in 1860 (44), (45 and 46) are mentioned.

On the other side of this controversy, reference is made to the opinions of a French scientist, De Gemini, in 1848 (34) and Mr. Rottier in 1862 (78).

Following this was an investigation undertaken by Mr. Charles Coisne, Engineer to the Belgian Government (17), (18), (19), (22). He also was on the side of those not inclined to exaggerate the value of carbolic acid as a permanent antiseptic. Practical methods of his experience are interesting, and this is how the author describes them :

“ Wood shavings were saturated with these oils in the following different ways :

“ 1st. With the creosotes as received.

“ 2nd. With the creosotes, supplemented by additional quantities of tar acids.

“ 3rd. With the creosotes, supplemented by some of the heavier portions of the same oils distilling over at a temperature exceeding 320° Centigrade (628° Fahrenheit).

“ 4th. With the original creosotes divided into the lightest, the medium, and the heaviest portions, with each of which the shavings were separately saturated.

“ A putrefying-pit (*pourrisoir*) was prepared, in which the shavings were placed on the 10th of November, 1866, together with other shavings not prepared. After four

¹The term “carbolic acid” is in the Paper often used as a generic term to embrace all the tar acids found in the distillates of coal-tar.—Ed.

years' sojourn in the *pourrisoir*, they were removed and examined on the 16th of November, 1870. The results were strikingly in favour of the heavier oils, and adverse to the tar acids, which last bodies appeared to have been wholly ineffective."

"Mr. Coisne believed that the best portions of the oils were the 'green oils,' distilling at high temperatures (17), (22)."

The consequence was that the Belgian State Railways stipulated that at least two-thirds of the creosote to be used "must have been obtained by distillation at a temperature exceeding 250° Centigrade (482° Fahrenheit), and the remainder at a temperature exceeding 200° Centigrade (392° Fahrenheit). It allows 30 per cent. of naphthalene, which is calculated at the ordinary temperature."

The Author goes on to draw attention to the fact that De Gemini, Rottier and Coisne, and various authorities in England, Scotland, France, Belgium, Germany and America (80 to 94), are agreed as to the volatility of carbolic acid at ordinary temperatures, and that its combinations are not stable, but usually wash out of substances intended to be preserved. Sir Joseph Lister and Dr. Sansom are quoted (83 and 90). Referring in detail to Mr. Coisne, he says that :

"In 1867 Mr. Coisne obtained some creosoted sleepers which had successfully resisted decay during periods of from eighteen to twenty years. The wood was crushed, and the substances obtained therefrom tested. He found no tar acids ; if they had ever been there, they were no longer present. He found, however, a quantity of naphthalene ; also of an oil which did not commence to distil until 230° Centigrade (446° Fahrenheit) (18), (22)."

There follows a detailed account of some very minute

and painstaking researches made by the Author into specimens of old sleepers provided by the North Western Railway Company and other railway companies, for the details of which we advise a careful reading of the treatise. The references in Appendix F in connection with these experiments are (1) and (2).

Mr. Greville Williams also tested portions of the same timber (28), (100b). In all the specimens, save two, he found naphthalene. The presence of the antiseptic alkaloïds was distinctly proved, and one of these bodies, called cryptidine, which he had discovered in creosote oils in 1856 (31), (99), was detected by him in one of the specimens. Mr. Greville Williams concludes that the preservative action of the creosote oils is due more to the bases or alkaloids than to the tar acids, as the former remain after the latter have disappeared.

Reference is then made by the Author to Appendix C and Plate 3, in which the constituents of the creosote oils were arranged in the order of their respective volatilities (80 to 94). Slight emendations have been made to these tables. He concludes by remarking about naphthalene that it becomes solid at a low temperature, but that the difficulty of injecting it into timber disappears at about 100° Fahrenheit, and that it afterwards solidifies in the wood and fills up the pores (50), (51), (52); (53), (100).

He then further enlarges upon the experiments which proved—what now seem to us the obvious facts—that, the lighter the oils, the more evaporation there is (Appendix G).

Experiments by Dr. Meymott Tidy point to the same results (54), (97), (30).

The Author continues :

“Following in the series of distillates, amongst the creosote oils are the alkaloids or bases of the quinoline or

leucoline group, amongst which chemists are searching, not without fair promise of success, for a febrifuge similar to, if not identical with, the quinine derived from the cinchona plant. In this group occurs the substance called cryptidine (28), (29), already alluded to as one of the valuable antiseptics discovered in those portions of the oils which were formerly characterized as 'inert.'

"Para-naphthalene was excluded by Dr. Letheby from the oils intended for timber preserving, and is probably without value for that purpose. It is now called anthracene, and is extremely valuable as the substance from which alizarine is manufactured, thanks to the brilliant discoveries of Perkin in England, and of Graebe, Liebermann and Caro in Germany. Alizarine is the colouring matter used by Turkey-red dyers and printers; for ages it had been extracted from the madder root (25)."

"Amongst the green oils, distilling between 550° Fahrenheit and 750° Fahrenheit, is found the acridine already alluded to as a valuable germicide and stable antiseptic (1), (2). Phenanthrene, carbazol, pyrene, chrysene and benzerythrene, by no means complete the list, which is constantly being added to by new discoveries of the numerous bodies in which these dead oils are so prolific."

Continuing his stand against the importance which had been attached to tar acids as a preservative, the Author "ventures to express the hope that at least the lighter portions of the tar acids, and especially carbolic acid, may soon be relegated altogether to their important functions as sanitary antiseptics, for which they are so valuable; instead of being wasted by the attempt to use them as antiseptics for timber, for which their peculiar properties render them unreliable. No oils, however, should be used as creosotes which are lighter than water. Both bone oil

and shale oil are sometimes offered as creosote oils " (Appendix D). The trend of scientific opinion in the direction indicated is referred to by quoting a specification drawn up by Sir Frederick Abel and Dr. Tidy (96) in 1881.

Conflicting Theories on Putrefaction—The Germ Theory

A very interesting and illuminating dissertation follows on the Germ Theory, as propounded by Liebig, and the allegation that the coagulation of albumen preserves the wood, and the contradiction of some of Liebig's theories by Pasteur, as confirmed by Professor Tyndall (22), (84), (63), (47), (98), (56).

The experiment mentioned in the subsequent discussion, which convinced my father that the coagulation of albumen did not sensibly arrest decay, was one with a hard-boiled egg in a Highland home, in which the Editor was personally concerned. We were told that the spores produced revelled in the name of *Micrococcus prodigiosus*. I notice that another name has been assigned to it later on by my father.

At this stage of the Paper the Author remarks that :

" The bodies of mammoths preserved in ice through countless ages, the trees of primeval forests excluded from the air beneath thick deposits of peat, the fragments of wooden piles which have endured undecayed for centuries when driven deeply below the surface of water, all confirm the experiments of Pasteur and Tyndall, and prove that the exclusion of germs prevents putrefaction."

" It is not for the Author to draw the dividing line between the decomposing action of germs and the action of

oxidation. It is sufficient for his purpose to submit that all influences which either destroy or exclude germs, will prevent decay so long as those influences endure ; but that permanent effects must not be relied upon from agents which are not themselves permanent and abiding. A growing scepticism arises from experience as to insoluble compounds being formed between woody fibre and substances which are themselves soluble in water. In short, the substances to be employed should by preference be antiseptics in a double sense ; they should be both germicides and germ excluders. From the long list of germicides must be especially excluded such as injure or weaken the fibre of the wood ; amongst these latter must be classed all solutions with very strong acid or alkaline reactions ; also some of the metallic salts. It has been seen that the salts of zinc, mercury and copper have been to some extent successful ; of these the Author's experience induces him to prefer sulphate of copper, as less soluble in water than chloride of zinc, and not volatile like corrosive sublimate. Even sulphate of copper cannot be permanently relied upon, when exposed to the continuous action of water ; but it may be found useful in comparatively dry situations, or as a protection against dry-rot to timber under cover. From its properties as a germicide, sulphate of copper might be usefully employed in conjunction with oily or bituminous fluids, even with oils which do not possess great potency as germicides " (12).

Apparatus for Preserving Timber

There follows an account of the various methods of applying antiseptics to wood, beginning with the tar brush and continuing with the steeping of timber in tanks, and

going on to the various methods of injecting by means of vacuum and pressure employed by Mr. Bréant, in 1831, in France. Mr. Bethell's patent of 1838 is next mentioned, and though this is not included in the original Appendices, it has been thought well to include it in this publication (Appendix A). Improvements by Burt, as detailed in his Paper before the Institute of Civil Engineers in 1853, are mentioned (6 and 20), and a patent taken out by the Author in 1865 (10). Two other diagrams have been substituted in the present publication for the one in the original work (Plates 1 and 2).¹

The process of Dr. Boucherie (15), in connection with the sulphate of copper process, is mentioned, as also various attempts to impregnate timber with the vapours of oils (39 and 49). The objection to injecting timber with oils under a state of vapour is mentioned as follows :

“ If this could be conveniently or safely carried out, the system might possess some advantages. But there is a fatal objection to its employment. Timber is weakened by exposure to a temperature much exceeding 250° Fahrenheit, whilst at 300° Fahrenheit, or a little above, it commences to decompose, and becomes seriously injured. Now the boiling point of the creosote oils ranges from a little below 400° Fahrenheit up to about 760° Fahrenheit. As with the steam of water, so is it with the vapour of oils—no pressure can be obtained with them, except at a temperature exceeding their boiling-point. The vapours of the creosote oils cannot, therefore, be injected into timber except at temperatures and under conditions of pressure which would destroy the value of the timber as an engineering material.”

¹It is not thought necessary here to give more than the reference numbers to various devices for mitigating the ravages of sulphate of copper and corrosive sublimates on the plant employed in the preservative processes, as these matters are of almost academic interest at the present day.—Ed.

The modification of the system is then mentioned by which superheated steam was passed through creosote oils and then injected into the sleepers, so that the mingled vapours of water and creosote might be injected into the timber at a temperature of 190°–320° Fahrenheit, but it is mentioned that the operation was supplemented by the injection of creosote in the usual fluid state.

The reason why this process was discontinued on the Western Railways of France was because “ it was found, whenever the cylinder was opened before the second operation, that a small portion of the lightest particles of the creosote had been carried over mechanically into the cylinder by the superheated steam. Once within the cylinder, however, the two fluids obeyed the laws which govern their respective volatilities: the creosote oil sank to the bottom of the cylinder, and the vapour of water only was injected into the timber. The sleepers, on examination and testing by the ordinary tests, contained neither tar oils nor tar acids.”

Similar attempts were made on the Austrian North-West Railway (79).

Condition of Timber at Time of Preparation

Getting rid of Moisture by Stacking or Artificially

Reference is made at some length to the scientific and common-sense facts connected with the methods of getting rid of the moisture from timber before impregnation, (63), (13), (25), and the drawbacks to any system of artificial

drying by steam, by ordinary and superheated currents of hot air and in stoves or ovens, because "to subject timber to a dry heat, elevated enough to remove its moisture with the necessary rapidity, will invariably result in injury to the wood. Timber piles stoved before creosoting prove brittle when driven. The action of the air-pump in the ordinary process assists the operation by withdrawing air from the pores of the wood; but it is a mistake to suppose that it has much effect in withdrawing moisture."

Next comes a description of the well-known Boulton patent, by which these difficulties were got over by making use of the facts: firstly that the boiling-points of all liquids are lighter under vacuum, and, secondly, that the boiling-point of creosote is considerably higher than that of water (11), (14), (26), (Plate 2). The creosote is introduced under pressure, at a temperature exceeding the boiling-point of water, when, "the heat being communicated through an oily medium, will not injure the timber, from which the water is volatilized and drawn out by the air-pump. The creosote oils are not volatilized, as the temperature is far below their point of ebullition. The water is speedily and effectually removed, and the creosote takes its place."

It has been thought wise here to give in its entirety the full text of this patent which, though it has long expired, has given the lead to wood preservers all the world over, and is admittedly the basis of the recent developments, across the Atlantic, in the treatment of Douglas fir and other woods in their green state, which engineers have found difficult to impregnate to their satisfaction even when thoroughly air-dried.

After a few concluding remarks as to the desire of the Author to advance no opinion which has not been confirmed by careful and reiterated experiments, the Paper

concludes by reference to the diagrams showing the Plant for the Distillation of Tar and a Genealogical Table of various derivatives of coal and coal-tar. These have both been considerably amended in the present publication, replacing the diagrams given in the original publication (Plates 1, 2, 3).

Discussion

The discussion which followed the reading of the Paper occupied two evenings. It was opened by the President of the Institution, SIR JOSEPH BAZALGETTE, C.B., who complimented the Author on having treated the subject on a higher level than on a mere commercial basis.

The Author then proceeded by stressing the point he had endeavoured to make in the Paper as to the close connection between the durable results of an antiseptic and the immunity of that antiseptic from volatility in the air or solubility in water, and he hoped that engineers would take the trouble to follow out this idea, and "study the different constituents of the creosote oils, remembering which of them were the most durable and the least soluble; that would give a clue to the formation of fresh specifications for the preparation of timber." He referred to the Genealogical Table (Plate 3) of products derived from Newcastle coal, and explained that there was a variation in the products from Midland coals.

DR. C. MEYMOTT TIDY

He mentioned that Dr. Tidy, who had drawn up the original creosote specification, said that he had considerably modified his views since the early days. Dr. Tidy had

now arrived at the stage in which his latest specification¹ showed "that the creosote should be completely liquid at a temperature of 100° Fahrenheit, no deposit afterward taking place until the oil registered a temperature of 93°. That point was considered very fully. The temperature at which creosoting was performed was about 120°. It did not appear to him to matter one iota how solid the creosote was (and he was bound to say that from his point of view the more solid it was the better), so long as it was liquid at the temperature at which the creosoting process was done." "The next point was (he had left out a specific-gravity clause) that, tested by a certain process, the creosote should yield a total of 8 per cent. of tar acids."

Dr. Tidy then gave obvious reasons why, in agreement with Mr. Greville Williams, his enthusiasm for tar acids as a component antiseptic had considerably cooled. "In the other part of his specification he admitted that he had completely altered previous specifications, namely, in requiring that the creosote should contain at least 25 per cent. of constituents that did not distil over at a temperature of 600°. He entirely agreed with the Author that it was to the heavier oils that the success of the creosoting process was due."

DR. H. E. ARMSTRONG

Dr. Armstrong found himself in agreement on the whole with the views expressed by the Author, and he predicted that before many years Dr. Tidy would drop his limit from 8 per cent. to 6 per cent. of tar acids and perhaps eventually sink it altogether. Nor did he think that the coagulation of the albuminoids took place to any

¹ See Mr. Fergusson's Paper for history of the development of later creosote specifications.

large extent or was an essential part of the process. His remarks emphasized the belief that the importance of creosoting consisted mainly in the choking action, by which he apparently meant the filling of the pores of the wood with a substance which would exclude moisture or the elements of decay.

PROF. A. VOELCKER

Professor Voelcker, who followed, was not inclined to go so far as Dr. Tidy in his disbelief in the importance of tar acids; "but he would go so far as to say that for preserving well-seasoned old timber it did not, perhaps, matter so much whether there was a high percentage of carbolic acid in the creosote, as it mattered that there should be present in it a high percentage of the oils which passed over on distillation above 610° , because, as Dr. Tidy had pointed out, the effect of those tar compounds was to close up the pores of the timber, to render it impervious to water, air and other debasing influences; being at the same time in itself, comparatively speaking, an imperishable substance, like all pitchy products when completely dried. But it should be borne in mind that it was requisite not only to preserve well-seasoned old timber, from which the moisture was expelled almost completely, but that of late years a great deal had been done in preserving telegraph-posts, gate-posts, wooden fencing, hop-poles, and the like, for which sapling-wood, or at any rate young wood, was used." The primary causes of decay of green wood were unquestionably the albuminoid substances; and all the older processes, such as impregnation with corrosive sublimate, zinc chloride, or other metallic salts, were based on the principle that by those metallic salts, notably by the bichloride of mercury (corrosive

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sublimate), the albuminoids were precipitated, and rendered insoluble and incapable of acting as ferments. In green wood, also, the cellulose was in a more tender condition than in old wood, where there was a larger proportion of encrusting matter ; there was, therefore, a greater reason for preventing the first state of decomposition ; and he questioned whether creosote, which was sometimes extremely poor in carbolic acid, was the proper material for preserving wooden structures of the kind he had mentioned.

After commenting on the different compositions of various creosotes, he gave it as his opinion that creosote containing as little as 5 per cent. of crude carbolic acid was not a good liquid for preserving immature wood, " simply because it was not strong enough to precipitate or render ineffective albuminoid substances." In further remarks he emphasized his opinion that a creosote suitable for seasoned wood was not suitable for green wood.

MR. H. K. BAMBER

Mr. Bamber not only stated that the results of comparative experiments made by himself with heavier and lighter creosotes differed materially from those of the Author, but he apparently disagreed with Sir Joseph Bazalgette's estimation of the plane attained by the Paper, and suggested that the increasing value of tar acids had, for commercial reasons, affected the Author's estimation of their value in creosoting, and that it was quite possible that, should naphthalene, which occurred in large quantities in the heavy creosotes, become valuable commercially, chemists would again be asked to reconsider their creosoting specifications.

DR. A. J. BERNAYS

Dr. Albert J. Bernays thought that "the substances preferred should be germ excluders as well as germicides, and those contained in the oils which were heavier than water. His contention would be to retain, at least in part, and to the extent of 2 per cent., the carbolic acid as well as the naphthalene and the alkaloids. The arguments in favour of carbolic acid were very strong. It said much for the durability of carbolic acid that, in spite of the employment of heavier types of tar creosote in early days, it was distinctly present in many cases recorded in the experiments of Mr. Greville Williams. The power possessed by phenol for coagulating albumen could not be exaggerated. He would not describe his own experiments ; but in his hospital work he was very familiar with the high antiseptic power of carbolic acid."

His further remarks were highly technical and are well worth reading in the original transcription of the discussion.

MR. W. FOSTER

Mr. W. Foster referred to a Paper he had recently read before the Institution. He was interested in the question of the five or six nitrogenous bodies mentioned by the Author, but thought there were probably others besides acridine present in pitch. If these substances had any value in the preservation of wood, their effect must be very powerful.

He then referred to the corrosion of iron, and said that pitch was, he believed, the best preservative from rust. Pitch was a substance of a most permanent character, being almost destitute of any chemical attributes ; if, therefore, the cellular structure of the wood could be thoroughly permeated by it, as long as the continuity

was perfect it would be preserved. In the case of green wood, the question arose as to the coagulation of albuminous matter. "The Author had referred to the experiments of Pettigrew; but the inference he had drawn was not the only one. If albuminous matter was dried, it could be kept as a horny substance for an indefinite length of time. A piece of glue could be preserved intact in the same way. If white of egg or glue were moistened and exposed for a certain time, it putrefied."

MR. W. CARRUTHERS

Mr. Carruthers thought that the botanical aspect of the question was important. "He acknowledged the great importance of pitch for preserving the external surface of wood. But wood decayed, not only from chemical agents, air and water, but much more from the action of fungal parasites. They were developed from spores and the attack might be made through a flaw or crack in the wood. He exhibited a specimen of wood the date of the creosoting of which was not known, but it had been used in a hurdle for at least ten years. The lower creosoted portion, embedded in the earth, did not show the slightest injury; but the upper part, exposed to the air and cracked, had been attacked from the outside by minute vegetation. The same thing had occurred in the case of two specimens of telegraph-poles. It appeared to him that what was needed was a sufficient impregnation of the wood with creosote, and with that element in it which was destructive to vegetable life."

He affirmed that carbolic acid was extremely destructive to vegetable life, though, according to Koch, a small percentage was not sufficient to destroy fungi. "Another specimen from a telegraph-pole had been completely destroyed by a fungus (*Reticularia*). There was on one

side a yellowish dust, consisting entirely of the spores of the plant. But in a specimen from a hurdle, which had been in use since 1861, when it was creosoted, the exterior, although it had no coating of tar, still exhibited the minutest marks of the tools employed upon it, and the interior, which was completely saturated with a brown substance, was as good and fresh as if it had been creosoted yesterday, without a particle of fungus. It appeared to him that there had been a new combination through the injected material, producing an antiseptic condition of the wood which was fatal to the fungi."

MR. H. MAUDSLAY

Mr. Henry Maudslay did not deal in his remarks with the creosote controversy, but gave a number of very interesting particulars with regard to the condition of wood when buried for many years under water and on land, which are well worth reading.

MR. E. A. COWPER

Mr. Cowper, in upholding the value of creosote, called attention to various instances of success and failure, and in the latter case maintained that the failure was from insufficient impregnation rather than from any other cause. He mentioned the Victoria Dock fence, which had been well creosoted and was as sound as it was twenty-nine years before, when it was put down.¹ He was on the side of the heavy oils, and quoted Mr. Charles Coisne's experiments as instructive in that direction. He had himself seen the working of the apparatus,

¹ This fence, erected in 1855, was eventually removed in 1921, but not because it had decayed. Specimens of part of the posts which had been *in situ* for over 65 years are now to be found all over the world. I last saw one at the works of the Vancouver Creosoting Company.—Ed.

described by the Author, for expelling the moisture from timber by the action of the creosote oil itself, heated to a temperature of 230° .

MR. W. H. PREECE

Mr. W. H. Preece, of H.M. Post Office, referred to the success which had attended the creosoting of telegraph-poles.

“ In 1844 the first line of telegraph was constructed between London, Southampton and Gosport, and the posts were made of best Memel timber, preserved by the Burnettizing process, simply impregnating the wood with zinc chloride. In 1857 he made a personal observation of a great part of the line in different grounds, and found that in sand about 40 per cent. of the posts had gone, in clay about 33 per cent., and in chalk about 28 per cent. In 1860 he found that the proportion was much greater, and in 1871 they had all failed, so that they had to be removed.

“ The favourite process about twenty years ago was that of Boucherizing.

“ While the life of an average telegraph-pole unprepared was about seven years, the life of a Boucherized pole was about fifteen years. In 1848 a line of poles was erected from Fareham to Portsmouth, a distance of about twenty miles, and all the poles, three hundred and eighteen in number, were creosoted by Mr. Bethell. In 1861 he examined them all *in situ*, and only two showed the slightest trace of decay, and they had begun to decay at the top.

“ Last year, owing to the requirements of the service, the line of poles had to be taken down and they were as sound as when they were first erected.

“ At present the millions of poles existing in the country were all creosoted. It was true that some of them had

failed ; but, as Mr. Carruthers had pointed out, there was creosote and creosote. There were unreliable firms, and others in whom confidence could be placed."

Correspondence

Between the discussion and its continuation on the subsequent evening, a certain amount of correspondence had been received by the Author of the Paper, and his further remarks, therefore, included a reply, not only to verbal remarks, but to those received in writing.

MR. A. BOUISSOU

Among the correspondence was a communication from Mr. A. Bouissou of the Western Railways of France, testifying to the success of beech sleepers, creosoted by the Bethell process, which had been put down in 1859 and exhibited in the Paris Exhibition in 1878. "It was shown that not a single one of them bore the slightest trace of decay." The subsequent experiments of his railway had confirmed the favourable behaviour of creosoted beech sleepers.

MR. W. A. BROWN

Mr. W. A. Brown confirmed the impression produced by the Paper of the failure of what was called "Mr. Blythe's system of 'thermo-carbolization,'" for the reasons as given in the Paper.

MR. JOHN CLEMINSON

Mr. John Cleminson did not find himself in agreement with the Paper as regards the Author's minimizing the

value of carbolic acid in creosote, and he laid more emphasis on the coagulation of the albumen than did the Author. He stressed the importance of care in the selection of timber. Unlike Mr. Brown, he was in favour of Mr. Blythe's system.

MR. R. COWPER

Mr. R. Cowper observed that the preservation of timber "depended partly on the mechanical effect which it had in excluding from the pores of the wood air and water, and the germs of destruction which they contained, and partly on the power possessed by certain of its constituents of destroying the germs." In his opinion the heavier portions of the creosote were most valuable, but he did not believe in the prominent value of the coagulation of the albumen.

MR. R. B. GRANTHAM

Mr. R. B. Grantham submitted the following information respecting the duration of timber on the Great Western Railway system, which had been supplied to him by Mr. W. L. Owen :

	Years
Uncreosoted yellow pine	12
Creosoted yellow pine in bridges, viaducts, or	} Bridges, &c. 20
in permanent way	
Timber prepared in any other way	12 to 15
Sleepers creosoted (Baltic)	8 to 10
Sleepers not treated, but used clean	5
Sleepers kyanized	6 or 7

Name of Railway	Date of Opening	Estimated Percentage of the original timber now in line	Remarks
Uxbridge Branch	1856 Sept. 8	50	
Henley Branch	1857 June	80	
Witham to Strepton ..	1858 Nov. 9		
Brentford Branch (narrow gauge added in 1861, ? clean timber)	1860 May 18	80	In two lines, narrow gauge creosoted. No clean timber in the branch now
Hungerford to Devizes ..	1862 Nov. 11	50	
Thame to Kennington Junction	1863 Oct. 21	80	
Wycombe to Thame (a great deal of Baltic timber was permitted to be used between Risboro' and Oxford. What result?)	1862 Aug. 1	80	
Marlborough Branch ..	1862 April 14	50	
Oxford to Reading ..	1856 Dec.	Nil	Reading to Didcot
(Narrow gauge? Common rail, just new; old common rail moved for narrow gauge)		15	Didcot to Oxford, 1856, narrow gauge
Paddington to Reading (A good deal of clean timber was used in the narrow gauge)	1861 Aug.	Nil	Paddington to Slough. All the clean timber was taken out in 1883
		75	Slough to Reading. Creosoted timber. All clean timber taken out
Reading to Basingstoke ..	1848 Nov. 1	25	Not on pine packing
Southcote to Hungerford	1847 Dec. 21	70	Pine packing
Didcot to Oxford	1856 June 12	Nil	
Didcot Loop	"	"	
Weymouth and Portland Railway	1865 Oct. 16	"	
Thingley to Frome ..	1848 Sept. 5	75	Thingley to Holt
	1850 Oct. 7	45	Holt to Frome
Westbury to Salisbury ..	1851 Sept. 9	70	
	1856 June 30		
Frome to Dorchester Junction	1857 Jan. 20	20	
Devizes to Holt	1857 July 1	95	

MR. W. LANGDON

Mr. W. Langdon, as an old believer in the efficacy of creosoting, regretted that the oils now employed did not contain that amount of tar or other heavy compounds which was apparently possessed by the creosote in earlier days. "If telegraph-poles creosoted many years back were examined, as a rule the surface of those poles would be found covered with a pitchy compound, and that mainly on the side of the pole exposed to the sun. There was no washing out from the weather. This he thought was easy of explanation. The warm atmosphere would always exercise an extractive influence upon any oil injected into wood or other like substance ; its tendency would be to bring it to the surface, where the lighter portions would be evaporated, and the heavier portions congealed."

The creosoting process enabled a long life to be obtained for telegraph-poles, railway sleepers and other timber employed out of doors, "and he imagined that the heavier oils played a much higher part in procuring this immunity from decay, inasmuch as it was to these heavier oils that the exclusion of moisture from the timber was due."

MR. C. DE LAUNE

"Mr. C. De Laune Faunce De Laune remarked that the Author had attempted to prove that only a very small quantity of carbolic acid was necessary in creosote for the preservation of wood. He approached the subject with diffidence, as he laid claim to no scientific knowledge, merely discussing it from the purely practical side ; and because he had been instrumental in extending the use of creosote among landowners and farmers. The Author referred to his having used creosote too hot, and thereby having damaged the wood, much in the same way as if he had taken a warm bath too hot. He certainly

stated to the Author that he had used a material called creosote which contained a very small percentage of carbolic acid, and that the wood had failed to be satisfactorily impregnated with it in an open tank, even when submitted to a great heat ; but he scarcely anticipated that he would infer that it was his general custom to use extreme heat, as he only wished it to be understood that even under such conditions the creosote did not perfectly penetrate into the wood. The process of injection, in the case of telegraph-poles, might preserve them to an indefinite period, but such a course was frequently impracticable to the farmer, and in the case of hop-poles impossible ; wherefore an open tank was indispensable. For the last twenty years he had used creosoted wood, and the process had always been performed in an open tank. The wood was first cut to the required shape, and then immersed in the creosote which had previously been liquefied and warmed by a furnace built underneath the tank. No thermometer had ever been used to regulate the heat, and the only precaution taken was to prevent the creosote from boiling over, though it was sufficiently heated to make a few bubbles appear on the surface. Wood of all kinds had been used, and no difficulty in applying the creosote was at first experienced, but he believed that the creosote had gradually been becoming worse and worse, and so he submitted it to Dr. Voelcker for analysis, and got the following reply : ‘ Your creosote has a specific gravity of 1.103, and on being subjected to distillation yields only 61 per cent. of volatile oils, of which 4 per cent. are carbolic acid. My experience in creosoting timber, small as it is when compared with that of public companies, is large for a private individual, as I have at this time 46½ miles of fences where creosoted wood is used ; and whereas the system, when employed some years ago,

was satisfactory, the present results are as much the contrary. The pieces of creosoted wood exhibited by Mr. Carruthers were creosoted by me in 1866, and, as was pointed out by him, are perfect in their preservation. Unfortunately I have no analysis of the creosote then used, for such an analysis would prove that a material of the same constituents would be suitable for preserving wood in an open tank.' It was obvious, therefore, that a creosote was formerly used that could and did preserve inferior wood in an open tank perfectly, and which could be used so easily that no particular precautions as to the dryness of the wood were necessary, and it was in the hopes of ascertaining the component parts of the creosote which he once used with such admirable results that he ventured on these remarks ; for the creosote that he formerly used for preserving wood was as valuable as that which he was now using was useless and worthless, and all he asked of manufacturers was to give him material like that which he had before."

MR. W. LAWFORD

Mr. W. Lawford inquired why the Midland Railway had given up creosoting their sleepers.

MR. C. LOWE

Mr. C. Lowe attributed to the tar acids only a very small part of the actual results obtained by the application of creosote, and gave his reasons, which seemed to be in accord with the opinions expressed by the Author. He, like other contributors to the discussion, mentioned that the action of creosote in preserving timber was of a two-fold character: "first, a mechanical action, by which the wood was rendered waterproof from the filling up of the cellular tissue with matter insoluble in water ; second, a chemical or antiseptic action, due chiefly to the presence

of the tar acids. He considered the creosote best adapted for the 'pickling' of timber to be a creosote containing sufficient solid hydrocarbon, such as naphthalene, to be solid at a temperature slightly above the average climatic or other temperature to which the timber was to be ultimately exposed; at the same time, to prevent the attacks of parasitic insects, etc., the heavy tar acids should be present."

MR. T. E. M. MARSH

"Mr. T. E. M. Marsh, who had exhibited during the meeting specimens of timber used by the late Mr. Brunel in 1839, observed that these were fair samples of the bulk of the timber of the ribs of the skew bridge over the river Avon, at the Bath station on the Great Western Railway. The timber was cut from Memel balk, and was kyanized. It was quite sound after forty years' service. The kyanizing process had been employed extensively by the late Mr. Brunel in the early works of the Great Western Railway." Subsequently he had adopted creosote. Mr. Marsh remarked that "the tar from which creosote was prepared was not subjected to the extraction of so many chemical ingredients as was now the case, and the naphthalene, or salt precipitated was comparatively small, and considered of little value." He called attention to the great importance of seeing that the timber was well seasoned and dry, and said that some alarming cases of internal decay had been discovered, attributable to the neglect of such precautions. He called attention to certain reasons which accounted for the failure of creosote in certain instances, attributable to careless or imperfect treatment of the timber at the creosoting yards, and gave some valuable information as to instructions given to his inspectors in order to ensure efficacy of treatment.

MR. BENJAMIN NICKELS

Mr. Benjamin Nickels was interested in the mention of the compound acridine, to which he attached great importance as an antiseptic. He then gave some very interesting results of his own experiments with that substance. "The Author might, he thought, rest well assured that his statements concerning this singular tar product were in nowise overrated or exaggerated. As regarded the antiseptic character of acridine, he might mention that it was of high value, extremely small quantities being sufficient to arrest the change in many organic substances prone to rapid decomposition."

MR. MARTIN F. ROBERTS

The following quotations contain the gist of the observations made by Mr. Martin F. Roberts: "He wished to direct attention to a point which had influenced engineers in their preference for the so-called 'country oil,' viz., that of economy. Engineers would be aware that in drawing up specifications it was usual to stipulate for a certain quantity of creosote to be injected into a cubic foot of timber, usually 6, 8 or 10 lb., the contractor's price for creosoting being regulated according to the quantity specified; and it thus became necessary for engineers to consider whether, say, 8 lb. per cubic foot of the thick heavy London creosote penetrated as far into the timber as 8 lb. of the thinner country oils. He was sure all engineers would agree that it would not; and from his own experience he was able to say that with telegraph-poles, in many cases where 8 lb. of London creosote per cubic foot had been injected, it had not penetrated more than half through the sap wood; whereas a similar quantity of country oil would have penetrated completely to the heart wood, although of course the country oil

would not leave as large a deposit of solid substances in the pores of the timber. It was therefore desirable to consider whether it was better to have the sap wood completely injected with thin oil at a certain price, or the outer portion only injected with thick oil at the same cost ; and his experience led him to prefer the complete injection by the thin oil. His ground for arriving at this conclusion was that, although he had met with many samples of creosoted timber in which a portion of the sap wood had decayed where the creosote had not penetrated, he had never met with a case of timber having decayed where the creosote had penetrated, except in one instance in a Government telegraph-pole, referred to in the discussion ; and even in this case he thought it well to ask if the decay had taken place before or after creosoting ? ”

“ What was necessary was that the germs of decay in the timber should also be destroyed, and this could only be accomplished by bringing all that portion of the timber more liable to decay, viz., the sap wood, under the influence of a creosote of considerable penetrating power. If evidence in support of this assertion were needful, it would only be necessary to refer to the fact that engineers strictly barred the use of whitewood timber for telegraph-poles and other purposes, owing to its being found impossible in practice to inject creosote into whitewood to a greater depth than $\frac{1}{2}$ or $\frac{3}{4}$ of an inch from the surface, and whitewood timber so prepared either with London or country creosote was found to decay rapidly. It would appear that the best system of creosoting would consist in first injecting the timber with thin country oil, then running the thin oil off and filling the cylinder with London creosote, which being forced in by increased pressure would drive the thinner oil further into the timber, and the thicker creosote would hermetically seal the outer

pores of the timber. Failing this process, owing to its increasing the cost, it would appear advisable to use thin creosote, and if it was considered that thin oil did not sufficiently fill the outer pores of the timber, the process, at a trifling cost, could be supplemented by giving the timber a coat of hot tar."

MR. G. WILLIAMS

"Mr. Greville Williams stated that he regarded the Paper as the most valuable and exhaustive contribution yet made to the literature of the subject. He agreed with Dr. Meymott Tidy and the Author in considering that the value of the carbolic acid in creosote oils had been overrated. He believed that an oil from which the carbolic acid had been removed would sterilize wood, if thoroughly impregnated with it, partly by virtue of the organic alkaloids present, and partly by the protective influence of the heavier oils themselves." "He thought that no chemist, who had examined very old sleepers for carbolic acid, could come to any other conclusion than that the traces remaining were insufficient for their protection." "If the coagulation of the albumen by the carbolic acid were the cause of the preservation of the timber, how was it that this acid almost entirely disappeared?" "There could, he considered, be no question that naphthalene, although perhaps feeble as a germicide properly so called, was very valuable as a sterilizer; it was insoluble in water, and once in the wood clung to it tenaciously. He was also most decidedly in favour of the removal of all restrictions as to maximum boiling-point, and considered that if the oils were fluid at the temperature of injection (say 100° to 120° Fahrenheit), that was all that was needful. On the whole question, he found himself able to thoroughly endorse the conclusions of the Author

and Dr. Tidy, and he considered that specifications which excluded the use of London oils were framed under a misapprehension of the true nature of the condition requisite to afford a good creosote."

MR. BOULTON

On the second evening of the discussion the Author replied both to remarks which had been made verbally and to those which he had received in correspondence since the reading of the Paper.

He acknowledged the remarks of Dr. Tidy in his recent report to the Gas Light and Coke Co. (Appendix I), which were in accordance with his views. He believed that both Dr. Armstrong and Dr. Tidy would in time be led by the logic of facts to accept a much lower proportion than 8 per cent. of tar acids as necessary in creosote. He added further details as to the distillation of London tar and the contents of tar acids in the creosote over a series of years (Appendices J and G).

With regard to Mr. W. Foster, the Author hoped that that gentleman would continue his valuable experiments on the composition of coal. With regard to Mr. Foster's reference to the experiment of Pettigrew (68), "what the Author desired to point out was that the previous immunity from decay had not been the result of any chemical combination between the antiseptic and the tissue."

With reference to the jarring note that had been struck by Mr. Bamber, the Author, while naturally pointing out that this gentleman had been mistaken in his inferences, also criticized some of the methods of Mr. Bamber's experiments, and found himself at variance with the accuracy of some of the supposed results. Perhaps it is better not to dwell further upon this particular episode, but a great deal of time and trouble was taken by the

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Author to convince Mr. Bamber of what the Author considered to be his mistakes, and the following are the references in the account of the Author's reply: (30), (54), (47*a*), (55*a*), (40), (22), (Appendix I); (1), (2), (31), (32), which can be read in full by those who care to refer to the Proceedings at the Institution.

In reply to Professor Voelcker, the Author remarked that "The views of Sir Frederick Abel on all the most important points of a creosote specification were substantially the same as those of Dr. Tidy and of the Author. And what the Author considered to be the most important points were, first, that the presence in considerable volume of the heavier and least volatile distillates, i.e. those distilling at or above 600° Fahrenheit, must not merely be tolerated but insisted upon. That naphthalene, and the other usual semi-solid constituents, should be admitted, provided they were completely fluid at the temperature to which the creosote was raised when injected into the wood. It was known that these views had not been adopted by the Crown." "Respecting the point which he considered subsidiary to the other two, although not unimportant, viz., the percentage of tar acids, Sir Frederick Abel, as well as Dr. Tidy, had recently recommended a reduction, and the last word had not been said on this question. Professor Voelcker was mistaken in thinking that Dr. Tidy had recommended 8 per cent. of carbolic acid. The 8 per cent. was of total tar acids, including carbolic, cresylic, and all other tar acids which could be removed by a specified solution of caustic soda." "It could surely have only been by some misconception that Dr. Voelcker recommended an entirely new departure by asking for 10 per cent. of carbolic acid in creosotes used for young timber or sap wood, although he admitted the probable superiority of the heavier oils for timber

intended for railway sleepers and other engineering purposes. Dr. Voelcker had not produced the results of any original experiments in support of his views. The typical experiments which he asked for had been tried and recorded; they proved that carbolic acid and the lighter tar acids were not reliable as durable antiseptics for timber (78), (22), (100b)." "The late Mr. Bethell had even advocated the use of young wood in preference to older timber, because the sap wood absorbed the creosote so readily, and Mr. (now Sir John) Hawkshaw had combated this idea, not from any doubt of the preservation of young wood, but upon the ground that the engineer must choose for many purposes the kind of timber best adapted for resisting impact or heavy strains. Amongst the numerous successful specimens of creosoted wood which had been exhibited at the Institution during the discussion, and which had been taken from various railways after periods of endurance varying from sixteen to thirty-two years, nothing was more striking than the perfect preservation of the sap wood, although careful analysis had shown that the heavy oils, and not the tar acids, were the enduring agents of preservation (28)."

The Author next proceeded to trace the care taken by the Post Office in securing proper treatment for their poles. The French engineer, Mr. Bouissou, confirmed the experiments of Mr. Preece, both as regards the satisfactory results of creosote and, more important, of proper seasoning before creosoting. Reference was then made to the Paper contributed by Mr. William Langdon to the Society of Telegraph Engineers on the 25th of March, 1874.

"With regard, therefore, to the observations of Dr. Voelcker as to green or unseasoned timber, the Author would add the results of his own long and varied experience in this and other countries, by saying that the

attempt should never be made to inject creosote, or any other oily substance, without previously, or at the time of the operation, expelling watery moisture. Timber should not be felled whilst the sap was in it."

"As regarded the effects of living organisms, and the introduction of their spores through cracks in the wood, the views of Mr. Carruthers entirely agreed with those expressed by the Author. But what was the remedy? The botanical aspect of the question had not been lost sight of, from the days when Dean Buckland and others discussed at this Institution the question of timber preparation from that important standpoint, and it had not been overlooked in the modern systems of injection. Exogenous trees, whose annual growth took place by the formation of concentric layers of vascular tissue added externally, furnished the timber with which engineers had almost exclusively to deal. The softer and younger wood containing the greatest portion of albumen was on the outside; it was more liable to decay than the harder portions. It was the chief merit of the system of injecting under pressure that it precisely met this difficulty. The softer parts absorbed more of the antiseptic than the rest, the pressure followed the line of least resistance, the antiseptic fluid gorged the sap wood, and penetrated to all cracks or shakes. There was but little analogy between this method and the application of a surface coating of pitch, as although he recommended by preference oils of a heavy character, and containing semi-solids, the whole of these bodies were perfectly liquid at 100° Fahrenheit, the temperature to which they were usually subjected at the time of injection. On cooling, they solidified, not on the surface merely, but within the pores of the timber, which they sealed up against the incursion of the agents of decay. Mr. Carruthers had referred to the experiments of the

celebrated Dr. Koch. The researches of Koch, and of other German scientific investigators, were very damaging to the claims of carbolic acid as a germicide, and as a coagulator of albumen (81*a*)."

The speaker then went in detail into some of Dr. Koch's researches (90), and noted that Dr. Sansom had already referred to them (90). There were also the researches of G. Wolffhügel and G. v. Knorre (94*a*) and of F. Boillat, who followed up the experiments of Koch at Bern (80), all pointing in the same direction.

"Mr. Carruthers had spoken of the presence of free crystallized carbolic acid in the cells of a small piece of a wooden hurdle. But carbolic acid would not crystallize out of the oils holding it in solution; it could only be obtained in that state of purity by a long and complicated chemical process, and the crystals would immediately liquefy when exposed to the atmosphere. The minute particles seen by Mr. Carruthers were probably naphthalene, or one of the other semi-solids of the higher distillates of coal-tar." In his opinion Mr. Carruthers had been finally answered by the many authorities quoted in the Paper (Appendix H) (22), (28), (30), (31), (55), (78), (80).

The correspondence with Mr. C. de Laune was then referred to at considerable length, and is chiefly interesting in these days in showing how Mr. de Laune, as an agriculturalist, was in advance of his times in attempting to make use of creosote for wood preservation on a country estate. The Author pointed out to what causes he attributed the failures as well as the successes of Mr. de Laune.

The present editor would wish to remark here that it is not to be expected that the majority of landowners and farmers, with a limited quantity of material for treatment, can go to the expense of a pressure plant, but very good results can be obtained from immersion in open tanks. Contrary to what might have been expected, however,

statistics have recently been collected which give a record of no less than twenty-nine pressure plants existing on estates or farms in the United Kingdom. If good liquid creosote is obtainable, it is only necessary to allow the timber to remain immersed in the tanks for about twenty-four to thirty-six hours. If the weather be very cold and there is a tendency for the naphthalene to settle out from the oil, then the contents of the tanks should be at a temperature of about 100° Fahrenheit during the period of the immersion of the timber. At the end of about twenty-four hours the heating agent can be removed and the oil and timber allowed to cool. It must be more than half a century since the Kentish farmers have habitually treated the ends of their hop-poles with creosote, and many agriculturalists all over the country have for a long time practised creosoting in open tanks with satisfactory results, though no doubt the results from pressure plants would have been better still.

There must be many cases where the question is between untreated wood and tank immersion, treatment under pressure being out of the question. In the case of wood of small dimensions, such as farm paling, the immerser will at all events have the satisfaction of knowing that in proportion to its bulk the timber has attained a much greater degree of penetration than in the case of a telegraph pole or railway sleeper under pressure. Roughly speaking, a fence pale may absorb by immersion to the extent of 80 % of its total cubic contents, leaving a negligible area untreated, while a railway sleeper under pressure cannot as a rule enjoy impregnation to more than say 20 % of its cubic contents.

In reply to Mr. Cleminson as to why he had not alluded to the process of Mr. Blythe, the Author stated that he had already treated in the Paper the subject of attempts to introduce creosote oils into timber in the form of

vapour, which attempts in his opinion had been unsuccessful for the reasons given in the Paper.

In answer to a question by Mr. Lawford with regard to the Midland Railway Company, the speaker stated that in 1866, at a meeting of the Institution, Mr. Crossley, the engineer of that company, announced that, although he admitted that creosoting stopped decay, he had given up that process from a calculation of economy based on the assumption that, with very heavy traffic like that which prevailed over the lines of his company, the sleepers were worn out by hard work before they had time to decay. The Author would suggest that incipient decay of unprepared sleepers often set in at a very early period of their service, especially through cracks and bolt-holes; the fastenings of the chairs thereupon became loosened, and the mechanical destruction of the sleeper hastened. But Mr. Lawford would be glad to hear that the Midland Railway Company had again adopted creosoting; they had had large quantities of sleepers creosoted during the last few years.

In reply to Mr. Roberts, he had never found any difficulty in completely saturating the sap wood with the London oils where the timber had been sufficiently dried. He referred again to Mr. Coisne's experiments on the Belgian State Railways (22).

With reference to the process mentioned in the Paper for removing water from the timber at the time of creosoting (Plate 2), further experiments are detailed.¹

"Six square fir sleeper-blocks, each 8 feet 11 inches by 10 inches by 10 inches, saturated with moisture, were cut into 10-inch by 5-inch sleepers. One sleeper, A, from each block was prepared by the new method, the corresponding sleeper, B, from the same block, by the old method, so that in each instance the results with the two halves of the same log could be contrasted. Care was taken

¹ See also actual patent, Appendix B.

to choose blocks having the heart in the centre, and with the texture of the two halves as nearly as possible similar.

From the six sleepers A, water was withdrawn by the new process to the extent, ascertained by weighing the water, of 120 lb. ; yet the sleepers, when withdrawn from the cylinder after the process was completed, weighed 155 lb. more than when put in, thus showing that they had absorbed 275 lb. of creosote. As their total cubic contents were 18.57 cubic feet, their average loss of water was 6.45 lb. per cubic foot ; their average gain of creosote was 14.8 lb. per cubic foot.

The six sleepers, B, were creosoted by the ordinary process. Being, like the others, very wet, and having no moisture extracted from them, the result of their being weighed before and after creosoting showed an absorption of 116 lb. of creosote only, or an average of 6.29 lb. per cubic foot. The separate absorptions of these six sleepers were as followed : 9.04 lb., 4.52 lb., 2.9 lb., 6.13 lb., 9.36 lb., and 5.49 lb. per cubic foot respectively, thus illustrating the uncertain results of creosoting timber when too wet by the ordinary method. They were placed in the cylinder with a charge of ordinary dry sleepers, which took up on the average rather more than 10 lb. of creosote per cubic foot.

The result with sleepers A was interesting, as it showed that by the new process wet timber could have its moisture at once removed, and a large quantity of creosote injected without difficulty. All twelve sleepers, both A and B, were afterwards cross-cut at 6 inches, 9 inches, 12 inches, and at 4 feet 6 inches from their ends, the corresponding sections of A and B being contrasted and photographed. The sleepers A were found not only to have absorbed a large quantity of creosote, but the creosote was much more evenly distributed than was the case with the sleepers B."

The speaker then summed up the evidence which had been produced during the discussion as to the best class of antiseptics for timber. These antiseptics had been described:

1st, as coagulators of albumen; 2nd, as germicides; 3rd, as sterilizers, rendering the cells of the wood unfit for the development of fungi or bacteria; 4th, as germ-excluders, closing the entrances against the intrusions of the enemy.

With regard to the coagulation of the albumen, he quoted Sansom (90a) and Angus Smith (91) as being opposed to that conclusion, and then mentioned an experiment he had himself tried on a Hebridean Island,¹ in which he found that in a hard-boiled egg after eight days "the albumen was coated with various species of *Micrococcus cromogenes* and other agents of destruction. The egg had become a mass of corruption. Coagulation had not protected albumen from putrefaction. What was the result when coagulation was produced, not by heat, but by the action of an antiseptic body? Did not the result depend mainly, if not altogether, upon the germicide properties of the antiseptic, and upon its abiding presence? Or, thus produced, did coagulation *per se* effect a new combination with permanent results? In the case of carbolic acid, a host of investigators said, No" (80 to 91).

"Boillat had produced a perfect coagulation of albumen with an excess of carbolic acid, and the albumen petrified on exposure to the air" (80).

The speaker again repeated his disbelief of the coagulation theory as applied to timber preservation. He gave reasons, as the result of experiments, why he did not believe that carbolic acid lingered in the timber in some unrecognized form. He referred again to experiments by Mr. Greville Williams (28) and Mr. Coisne (22). The latter "had injected woody fibre with light oils and an

¹ This was in 1884 in the Island of Mull. By a curious coincidence I find myself correcting the proofs of this volume in 1930 in the adjacent Island of Iona.—Ed.

excess of tar acids, and the woods rotted, whilst the woods creosoted with heavy oils, and without any tar acids, were preserved " (22).

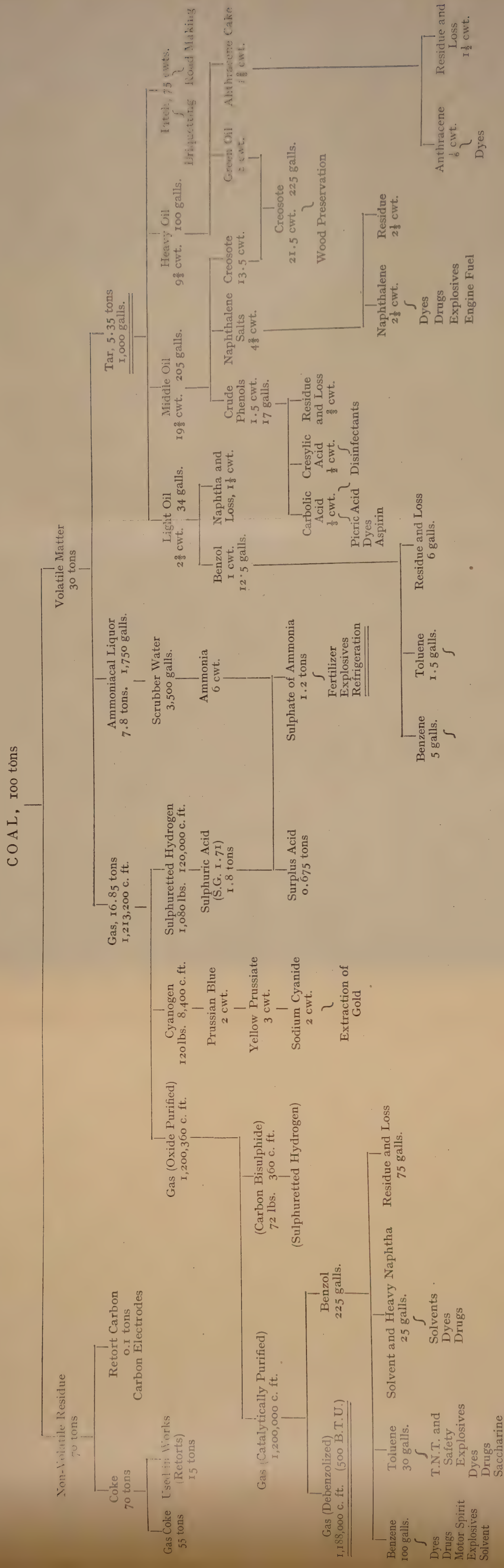
As regards the consensus of opinion on the discussion that creosoting was undeniably more successful as a preservative than corrosive sublimate, sulphate of copper or chloride of zinc, " Could this be at all due to carbolic acid, which was less permanent in its effects than the three metallic salts alluded to, and very considerably less powerful as a germicide than corrosive sublimate or sulphate of copper? " (Koch, 81*a*; Boillat, 80). " In a work upon bacteria by Magnin and Sternberg (2*a*), carbolic acid came low in the scale as a germicide." " To this must be added the statements that in oily solution the antiseptic power of carbolic acid was diminished, according to Sansom (90) and Angus Smith (91); altogether it was nil according to Koch (81*a*). " No chemist or practical man had produced a proof that carbolic acid had had any lasting effect upon timber.

As to the substances in creosote oils which had ensured the superiority of that process over the others (see Plate 3 and Appendix C revised), the Author then asked his audience to divide the bulk of the oils roughly in half, and proceeded to repeat his preference for what he called the right-hand half as against the left-hand half, which in their united bulk were perfectly fluid at a temperature of 100° Fahrenheit, and his distrust of the left-hand half (22).

He concluded with the following words :

" Timber preserved by antiseptic treatment was an engineering material competing with other materials, both as to price and durability. Members of the Institution would appreciate the endeavours of the Author to emancipate an important industry from the effects of any theories which, themselves unproven, might stand in the way of improvement, either as to diminished cost or increased efficiency."

CHART INDICATING THE VARIETY AND QUANTITY OF IMPORTANT AND VALUABLE BY-PRODUCTS RECOVERED FROM THE CARBONIZATION OF COAL AT THE GAS WORKS



A FEW REMARKS UPON
TIMBER PRESERVATION

BY

SIR SAMUEL BAGSTER BOULTON, Bt., D.L., J.P.
(Assoc. Member Inst. C.E.)

IN DECEMBER, 1909, Sir Samuel Boulton issued a short treatise as an addendum to his Paper, most of which is reproduced below.

A FEW REMARKS UPON TIMBER PRESERVATION

A word respecting the Body, for whose discussion my Treatise was drawn up, may not be out of place. British engineers were the pioneers of railway-making upon an extensive scale. And as regards Timber Preserving, the question became, at a very early period of railway-making, one of vital importance to them, seeing that the forests of Great Britain could not produce anything like a sufficient supply of railway sleepers, and it became necessary to obtain supplies at considerable cost from other countries. Railways for passengers and ordinary traffic may be said to have begun in England with the opening of the Stockton and Darlington Railway in 1825. The more important of the timber preserving patents were taken out from 1832 to 1838. All sorts of conflicting theories had been promulgated as regarded the causes of the decay of timber and other organized matter. All sorts of specifics had been recommended in a more or less empirical manner. But if (when I read my Paper in 1884) very little agreement had been arrived at as to theory, engineers had, nevertheless, upon a subject which deeply interested them during over fifty years, acquired valuable experience in practice. They had found out (theory apart) which were some of the substances most valuable for preventing the decay of timber. Scientists had to agree as to the reasons why.

I can well remember, in the course of my studies and experiments, the dismay which I once experienced on

finding that the conclusions which I felt compelled to arrive at on this subject were in opposition to the declared views of the great German chemist, Liebig. And my relief was proportionate when I found, after a careful study of the discoveries of Pasteur, that his theories exactly explained the experiences which had been acquired as to the action of various antiseptics in the preservation of timber. The dispute between Liebig and Pasteur was fought out as regards the nature and operations of ferments and the causes of the decomposition or putrefaction of organized bodies. Pasteur's doctrine (in opposition to the views of Liebig) that "without the presence of living germs, the phenomena of organic decomposition do not accomplish themselves, and that these germs are the veritable agents of the decomposition," guides us very clearly as to the choice of the antiseptics best adapted for the Preservation of Timber. It followed, then, that the antiseptic should not only be a *germicide*, but also a *germ excluder*. No substance which is readily volatile at ordinary temperatures or easily soluble in water can be permanently relied upon. The abiding presence of the antiseptic is necessary in order to prevent the decay of the timber, and it is necessary that the timber should also be rendered more resistant to changes of weather by having the pores filled with a substance which will prevent the absorption of moisture. The possibility of physical changes has to be considered as well as those resulting from organic growths.

It was upon these bases that I drew up my Paper in 1884. As I stated therein, the Records of the Patent Office contained lists of almost every conceivable antiseptic suitable, or unsuitable, for the Preservation of Timber. The *Traité de la Conservation des Bois*, by Maxime Poulet (Paris 1874), gives descriptions of an

astonishing variety of these proposed remedies which had turned out failures. But by 1884 all these processes had ceased to be seriously considered, except four, viz :

1. The heavy oils of tar, commonly called creosote.
2. Bichloride of mercury or corrosive sublimate.
3. Sulphate of copper.
4. Chloride of zinc.

Of all these four processes I have had extensive experience for railway sleepers, both in England, in France, and in various other countries. But creosote was rapidly, and in England almost entirely, superseding the other three, and at the present day, English engineers use creosote only. This in spite of the fact that the watery solutions of the metallic salts cost less than creosote. Pasteur's germ theory explains the fact that oily and bituminous bodies, in all ages of history, have been found to be the best antiseptics in general, and creosote or the heavy oil of tar, in particular, possess a marked superiority over the solutions of metallic salts as permanent antiseptics. *Creosote is a germicide and also a germ excluder.* The heavier portions of the creosote oils, which are their most valuable constituents, solidify in the pores of the wood and block them up from the intrusion of germs. It is for these reasons that creosote has in Great Britain for years past entirely superseded the use of the three metallic salts above mentioned for timber preserving, although all three are good antiseptics. But their effects are not sufficiently permanent owing to their solubility by water, and their volatility. The doctrines of Pasteur (proved and confirmed by Professor Tyndall, and numerous other scientific authorities) have not only shown the way how to choose antiseptics for timber, but they have cleared away theories which had no basis upon practice

or experiment, and which "darkened counsel by words without wisdom." We no longer hear of "phlogiston," a purely imaginary substance. We no longer discuss "eremacausis" as the cause of decomposition. "Spontaneous generation" (or "abiogenesis") has been proved to be a fallacy.

The coagulation of albumen, as has been proved to demonstration, is not the cause of the success of any timber antiseptic.

The temptation of "cheapness" in countries first confronted with the problem of using antiseptics for their timber is very great, especially when the price of creosote is, for the time being, from geographical reasons, comparatively high. Recently (although not in Great Britain) experiments have been made on a somewhat considerable scale by employing a mixture of chloride of zinc and creosote for the sake of economy. Creosote, an oily substance, and chloride of zinc in a watery solution, present the proverbial difficulty of mixing water and oil. I had studied this problem so long ago as 1883, when I took out a patent for the use of metallic salts in conjunction with creosote, the process being, first to impregnate with the solution of the metallic salt alone, next to withdraw that solution from the impregnating cylinder, and then to inject under pressure a certain quantity of creosote heated above the boiling point of water. The heat would evaporate the water of the metallic solution, which could be withdrawn by the air pump; the creosote would take its place, and would seal up the metallic salt within the timber. I prefer this process to the difficult attempt to mix water and oil.

The question of preparing wet timber is another important one. The proper absorption of creosote by timber is impeded if the timber be wet. To dry wet timber by

stacking is sometimes a long process. In 1879 I took out a patent for a simple process by which the whole of the watery moisture may be effectually drawn out during the process of creosoting, at a very small expense and short delay. It is needless to say that both the above patents have long ago expired, but the Government in England employ my process with great success in creosoting telegraph-poles.

I venture to think that a study of the prolonged and exhaustive experience of engineers in England will amply repay their confrères on the American continent, who are now confronted with the absolute necessity of husbanding the resources of their magnificent inheritance of forests. I should be very glad to answer any questions bearing on this subject which may occur to my friends on the other side of the Atlantic.

REMARKS BY THE EDITOR

REMARKS BY THE EDITOR

AT THIS POINT, and before inserting Mr. Fergusson's treatise which brings the history of creosoting up to date, the Editor would like to observe, with satisfaction, that it fell to him personally to give practical effect to the wishes expressed in the last paragraph of Sir Samuel's 1909 treatise, at all events as far as the Dominion of Canada was concerned.

By 1909 the engineers of the United States and Canadian railway engineers had been fully alive for some time to the necessity of employing wood preservatives. Canadian railway engineers had not at that time followed the example of the United States in a wholesale practical application of creosote to their sleepers. Many American and Canadian engineers even before that time and until the present day, have very generously expressed their gratitude for the help which Sir Samuel's experience had afforded them, but it was not till 1910 that, as a result of many personal talks with the late Lord Shaughnessy, the Editor was able to induce the Canadian Pacific Railway to take up seriously the question of creosoting their railway ties. The C.P.R. was followed by the Grand Trunk Railway at a later date, and to-day both the Canadian Pacific and the National Railways, which have practically absorbed the remaining railways of Canada, are creosoting millions of sleepers in conjunction with organizations initiated by the British and Canadian Companies in which the Editor succeeded Sir Samuel as Chairman.

LATER DEVELOPMENTS IN
WOOD PRESERVATION

BY

HUBERT FERGUSSON

LATER DEVELOPMENTS IN WOOD PRESERVATION

IT WAS MY PRIVILEGE to become associated with the writer of the paper on "The Antiseptic Treatment of Timber" a few years after its publication in 1884. The present essay is an endeavour to set down not a detailed synopsis, but a rough summary of the progress made during the last half-century in the later developments of wood preservation, in which I have been continuously engaged during that period.

Fifty years is a long time to cover in these days of rapid progress and easy interchange of ideas and thoughts. My earliest memories of creosoting are associated with a section of fencing in the Victoria Docks, London. Mr. Boulton refers to this as a remarkable instance of the preservative powers of creosote. Since then, from time to time, a post was dug up for exhibition purposes and so the association was confirmed and renewed, each post being in as good condition as the earlier removals, until in 1922 the fence was no more. It had not crumbled away, the landlord for reasons of his own cut down the fence, and no doubt used it for firewood. So, after about seventy years, this old and tried fence, capable of living over a hundred years, passed away instead of remaining as a monument to Bethel.

The earlier preservatives such as mercuric chloride, copper sulphate and zinc chloride (9), (43), (48) still continue to be used, and many processes have been proposed for overcoming their great defect—namely, that they are

not permanent and are subject to leaching when exposed to moisture. There have, of course, been proposals to use other metallic salts, with or without organic antiseptics extracted from coal tar or synthetically prepared. Some of these are old failures dished up under new names.

It is only a matter of a few months before a rank failure is discovered, but nothing but actual use over a long period will indicate the assured success of a preservative for any given timber. Soft wood untreated with any preservative may last three or even six years. A cheap preservative which added a few years to its life would, in the earlier days, have been considered valuable. With the increasing shortage and cost of replacement a few years' life is no longer sufficient and the preservative must be lasting in its effects.

During the period with which I deal, perhaps the most notable fact is the enormous increase in the preservative treatment of not only railway sleepers, but of many other forms of timber used in the United States and Canada, where the rapid wastage of immense natural resources became a menace. Formerly, on account of the difficulty in procuring creosote, metallic salts (mainly zinc chloride) were more in favour for the treatment of railway timbers. Gradually the facilities for obtaining creosote were largely increased until ocean installations on both sides of the Atlantic made return freights possible in the large tank steamers bringing petroleum from America.

To-day in both Canada and United States large tar distilleries have been erected to deal with the increasing production of their gas undertakings and steel works. It is possible that ere long North America will be able to supply all the creosote required there.

Dilution with cheaper oils such as petroleum residues (fuel oil, etc.) (101), (102) has been found to be soundly

practicable provided that the amount of diluent is not so large as to mask the antiseptic properties of the creosote. A fifty-fifty mixture has been found to be the optimum for petroleum and good standard creosote. It is claimed that such mixture gives better mechanical properties to sleepers than an equal quantity of "neat" creosote.

Emulsion with water and a little stabilizer was used in Russia in 1908, and further experiments have been made for my Company during recent years by Captain China, the inventor of a special colloidal mill, which gives very fine emulsions with extremely little stabilizer (103). Emulsions so prepared are no longer subject to selective filtration during impregnation—a grave drawback to the use of emulsions in the past.

Emulsion with aqueous solutions of metallic salts such as chloride of zinc has been in use in Germany and United States for many years (104), (105). It is, however, inexact to call the mixture an emulsion, because the existence of a permanent colloidal system is not possible in the presence of an electrolyte of the nature of zinc chloride, and separation takes place immediately. The process is carried out by having a centrifugal pump or emulsion nozzles in a circulating system in series with the cylinder and in operation all the time the impregnation of the timber is taking place.

Actual extraction of some of the creosote after impregnation seems to be the more sensible way where it is deemed unnecessary to have the fullest protection. This result is achieved by acting on the principle that most of the air in the cells, vessels and pores of the timber, remains therein and is compressed when the oil is forced in under pressure. On releasing the pressure, the expansion of the air to its normal volume will eject much of the oil.

If, after emptying the oil from the cylinder a vacuum be created, it is obvious that a further expansion of the air takes place and some more oil may be ejected.

This process must have been known to all operators of wood-preserving plants working under pressure, but Lowrie in U.S.A. obtained a patent for its application, and the process is generally known by his name (106).

Rueping in Germany goes further, and obtains a much greater ejection (or kick-back as it is frequently called) by using compressed air. That is to say, by means of an air-pump he raises the air pressure in the cylinder, already charged with timber, to four or five atmospheres above normal, and then without allowing the pressure to fall he replaces the air by oil. Then he raises the oil pressure by means of a force-pump to such height as will secure the required depth of impregnation. On releasing all pressure, the kick-back is very effective (107).

The British Post Office for some little time has had all its poles done by the Rueping process, considering the residual creosote sufficient to preserve them for the time they will be required to carry any given line. Apart from the saving in cost of preservative, the Post Office thus obtains poles which may be used on highways without fear of claims for damages due to the bleeding of any surplus oil. Another advantage is that paint will dry on the wood with little discolouration if a special first coat be applied.

These recovery processes are generally known as "empty cell" in distinction from the old or "full cell" process.

I have something to say later on about these attempts to economize at the expense of full protection.

As a last example of economical methods, I mention one which was dealt with by Mr. Boulton. That is the injection first of an aqueous solution of metallic salt, to a point short of refusal, followed by an injection of

creosote—or its variants. After the impregnation with the salts has been made, a certain proportion of the solution is removed by vacuum in order to allow of the introduction of creosote in the latter part of the process. The coat of creosote or tar after the solution seems to be the most obvious way of delaying the leaching, but a process known as the Wellhouse (108), at one time popular in the United States, was to follow the salt bath with a solution of glue and tannin. The tannin renders the glue insoluble during the drying of the impregnated wood. Other colloids and coagulants have been suggested.

The old story about the coagulants of albumen fully dealt with by Mr. Boulton still crops up in the B.M. Process (109), which employs a double solution of zinc chloride and aluminium sulphate to be injected at temperatures below 60° and thereafter raised above 80° Centigrade.

The ease with which zinc chloride is leached from timber has caused investigators to wonder why its powers of preservation should remain for even the moderate time observed, and the conclusion arrived at is that the formation of zinc oxychloride is greater than at first would be expected, and that this oxychloride is readily soluble in the secretions of the attacking fungi, thus poisoning their food. Working on this theory, Curtin attempted to produce solutions of two or more salts which would slowly react to form insoluble but strongly toxic compounds. The result of these researches has been the choice of a zinc-arsenic solution, which is claimed to gradually produce in the wood a zinc meta arsenite, practically insoluble in water, but strongly poisonous to fungi whose hyphæ are trying to penetrate timber containing this salt (110).

Then there are solutions which are claimed to form insoluble compounds with cellulose or liquose. The well-known effect of alkaline copper solutions on cellulose is

made use of in the solution known under the proprietary name of "Aczol" (111).

A proprietary preparation with which I have experimented consisted of basic oxides of copper and zinc, dissolved in ammonia, to which had been added some tar acids, chiefly cresol. It is claimed that a very dilute solution may be used and that the preservative effect is lasting. Specimens of sleepers, after years in the track, have been exhibited and certainly looked and were sound, but, unfortunately, with most of these "new" preservatives the test is not usually carried out to the bitter end under all the rigours of use in long sections of main line.

Another mixture known as Wolman Salts (112) uses sodium fluoride as its chief preservative constituent, but there is added an organic compound in the form of dinitrophenol, a body of strong antiseptic properties which fixes itself on the fibres of the wood after the manner of the synthetic dyes, many of which possess slightly antiseptic properties. There are variations of these proprietary mixtures made either expressly by the proprietors for special application or by others who hope to obtain protection for their mixture as a novelty.

A process named after the inventor, Powell, employed a preservative of a different nature (113). Powell was a sugar refiner, and in the course of his business had observed that wood saturated with sugar solution seemed to be immune to decay. His first attempts were to boil the wood in an aqueous solution of common sugar or molasses and leave the wood in the solution until cold. He claimed, with some reason, that not only had he armed the wood against attack of fungus, but had added to its desirable mechanical properties. He soon discovered that his wood was not proof against insects and rodents,

and accordingly poison had to be added—arsenic. In India, and more so in Australia, the process finds some favour (1114). A small plant operated outside London soon closed down. The solubility of sugar and glucose in water naturally reduced the quantity left in the wood when exposed in a damp climate, so that the protection period was shortened. An experiment I made with pine paving-blocks impregnated with a sugar solution indicated that the treatment did not in this climate confer any resistance to weather stresses. After treatment, the blocks were hung from a rail by string in the open air. After six months of alternating wet and dry weather the blocks were so badly shaken that some of them could be broken by hand. It may be that the good results in India and Australia were due to arsenic remaining in sufficient quantities to deter the white ant.

Whilst some inventors have been trying to find cheap and effective preservatives, others have been carefully studying methods of impregnation with a view to the satisfactory treatment of difficult timbers, and thus rendering serviceable many which were looked upon as of little use. The word “difficult” may be taken to cover several properties :

- (A) The timber may offer resistance to fluids both in the heart wood and sap wood.
- (B) It may absorb greedily in one part and absolutely refuse in another, although both parts may consist of the same type of wood, sap wood or heart wood.
- (c) The refusal may be due to the presence of excessive moisture or to an attack locally of fungus, such as blue sap (*Ceratostomella*) ; on the other hand, an attack of other fungus may render the wood more absorbent (1115).

The removal of moisture from timber by air seasoning or kiln drying is a lengthy or expensive process and does not always improve its condition. Air seasoning by stacking in the open, or even under a roof, is a variable affair which is out of control, whilst kiln drying, which can be scientifically controlled, is too expensive a process except for the more valuable timbers. Still, for most of the commoner timbers, which are subsequently to be treated, it is necessary to make room for the preservative. If an aqueous solution be employed that room must be made before immersion. On the other hand, Mr. Boulton, (11), (14), (26), showed that by his method green timbers could be quickly seasoned if the preservative were an oil. In this country where comparatively easily seasoned pine was almost exclusively used for sleepers and telegraph-poles, Mr. Boulton reaped much honour but little profit from his invention. As in the case of many other inventions, it was a new generation in a new country that began to find out what a valuable legacy he had left them.

America, the waster of her timber birthright, becoming alarmed when almost too late to save the situation, began as noted above a vigorous campaign of timber preservation. Her great variety of timbers from which to draw railway materials made it necessary to carefully re-study the question not only of preservatives, but of actual processes.

Now the problems of satisfactorily treating many different species of wood are difficult to solve, and are complicated by variation in age and size of the trees from which the sleepers are cut. In Europe and particularly for the English market, the selection of sleeper wood is made from trunks of the proper size, as any larger or older wood has its own more valuable uses (116).

At one time in U.S.A. steaming at about 20 lb. per square inch above atmospheric pressure followed by vacuum was much in favour, but this did not solve all the difficulties.

On the contrary, it was found that the timber frequently gained in water content (117). During the steaming, water is condensed, whilst the wood is being warmed up, and much is absorbed unless the pieces are already waterlogged. The water absorbed into, and that already locked up in the vessels and pores, does not follow the rule of "free" water boiling under diminished pressure. In other words, it requires much more energy to evaporate water in wood than in an ordinary container. Any improvement in impregnation which may be due to steaming must be ascribed to changes produced by the moist heat in the structure and in the contents of the cells, vessels and ducts. Mr. Boulton had shown how the desired results could be achieved under perfect control, although he never claimed for his process more than the removal of inconvenient surplus water.

On the Pacific slopes of the United States and Canada are vast forests of Red Wood and Douglas Fir. Both are difficult to creosote, and for many years were looked upon as useful timbers for situations where decay could not occur or whilst the cost of renewal was not serious. Ordinary air seasoning and pressure impregnation with creosote produced only very mediocre results as regards resistance to decay or physical effects. It was found, however, that the Boulton process applied to the unseasoned timber gave excellent results (118). Round piling could be easily impregnated with at least 12 lb. of creosote per cubic foot, whilst sawn sleepers, even all heart wood, could be given ten pounds per cubic foot.

Sleepers, however, could be given a more even impregnation if they were first incised, this treatment having the advantage of lowering the time required for the Boulton process.

One of the earliest attempts at systematic puncturing of "difficult" timbers was installed at the Hungarian Government Pole Yard at Puspockladany about 1911. The system was introduced by the engineer Haltenberger, its inventor. It consists of a sort of multiple drilling machine working upwards. It was intended for fir and spruce poles in order to obtain satisfactory impregnation of about three feet of the earth and air portion. The drill spindles were as closely spaced as possible, and the drills were wire nails with the heads cut off. There was practically no removal of wood, as the nails had no real cutting edges. After each stroke of the spindles the pole was rotated sufficiently to obtain the requisite spacing. During treatment with creosote, the oil spread from the punctures so that the band of protection was complete.

The incising machine (119) for treating squared timbers is something like a powerful four-cutter planer in which the revolving cutter blocks are replaced by rollers with knives or chisels mounted at right angles to the axis. The number of knives and their spacing can be varied in accordance with the properties of the timber. The slits are usually from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch deep. No wood is removed, and frequent tests show that the weakening effect is practically negligible, being less than 5 per cent: in the case of Douglas fir (120).

To-day enormous numbers of Douglas fir piles are used on the Pacific Coast, where *Teredo*, *Limnoria*, etc., will destroy unprotected piling in a few months. The younger generation know not their benefactor, and the

process is now generally termed "Boiling under Vacuum," very occasionally is the name of Boulton added.

Large quantities of Douglas fir are imported into this country, but extremely little receives the proper preservative treatment. Engineers appear to be averse to going to the extra cost of the Boulton process, so one hears frequent complaints of unsuitability, of only ten years life for sleepers, and so forth. A notable exception is the use of enormous quantities of Douglas fir by the Falmouth Docks and Engineering Co. This is squared piling treated at the works of the Vancouver Creosoting Co. (Branch of the Canada Creosoting Co.). Recently Burt, Boulton & Haywood, Limited, made a considerable extension to their wharves at Eling, near Southampton, and all the piling was of squared Douglas fir treated on the works by the Boulton process. The timbers were taken straight from the water to the plant.

Naturally, one uses a special process with all due consideration of what the ultimate effect may be or what state of finish may be desired. So, in treating timber to preserve it, one must not only know a good deal about the characteristics of the species, but particular attention must be paid to the pieces to be treated, the use to which they are to be put and the conditions of climate, etc., to which they will be exposed. With this knowledge, it is possible to apply modifications or combinations of standard methods. For instance, a combination of incising, Boulton and Rueping processes is usefully employed in treating Douglas fir sleepers. An injection of 12 lb. of creosote per cubic foot with a kick-back of 5 lb. leaves the sleepers well preserved and in excellent condition (121).

I have found that a further combination is useful in treating piling. It is what French engineers call a

“somersault process” (122). Several times during the progress of the Boulton process I break the vacuum and allow the pressure in the cylinder to reach that of the atmosphere (123). The intention is to replace some of the evaporated water by oil in easy stages and so reduce the tendency to shake; but another effect is that resin is softened and dissolved at a much earlier stage, thus facilitating the easier passage of the oil. It may also be useful to introduce the Rueping process at some intermediate stage. Finally, if “economy” of preservative be the object, the Rueping process may be the final touch, i.e. instead of applying the force-pump immediately after the boiling under vacuum, the cylinder is emptied and the whole operation of the empty-cell process is carried out.

Before leaving this branch of the subject to describe improvements in apparatus and lay-out of plant, it may be helpful to try to answer a “portmanteau” question: How and why do preservative solutions enter wood, and why do some woods offer resistance whilst others appear to be avid for the solutions?

I will take three examples, pine, spruce and beech. A superficial examination of sections under the microscope will indicate to the untrained eye that there is no difference between pine and spruce. Beech, on the other hand, appears to be traversed by many minute pores. The sap wood of pine (*Pinus sylvestris*) when dry (124) will absorb creosote so readily that satisfactory impregnation without pressure can be achieved in a few hours, or under pressure in a few minutes. Spruce, on the other hand, refuses even under high pressure to take more than a superficial quantity. Beech again, if sufficiently dry, can be deeply impregnated with comparative ease through its pores.

The examination of the sections mentioned above will have shown that the annual rings consist of two merging sub-rings of larger and smaller cells known collectively as Spring and Autumn wood respectively (125). Crossing these annual rings are the medullary rays, more or less continuous from inner bark to pith. These rays, being thin plates of cells or vessels, serve as the means of circulation and supply of the food products formed in the leaves. The Autumn wood also plays a part in the formation of at least the first cells of the next Spring wood. The circulation of water from cell to cell of the Spring wood is through bordered pits, but these pits are divided by a membrane with a thickening in the middle known as the taurus pad, large enough to act as a valve to the pit. The membrane itself appears to be porous, but should there for any reason be an excessive pressure in either direction the pad will close the opposite orifice of the pit. The cells of the Autumn wood, being responsible for the start of the next year's work, although similar in shape, are thicker walled and have to provide storage for the first food required for the new Spring wood. The Autumn cells have many simple pits, and apparently in giving up of their substance or contents to the formation of the first Spring wood, provide passages which eventually are practicable to the liquids of the wood preserver.

A pine sleeper treated with 10 lb. of creosote per cubic foot will exhibit the following characteristics. The creosote will have penetrated most of the sap wood, but the heart wood will have been scarcely touched except at the ends, where a penetration of six or more inches may be noted. It is obvious, therefore, that creosote has passed into the heart wood not radially, but longitudinally. An examination of radial, longitudinal and

transverse sections will show that the oil has penetrated the sap wood by way of the medullary rays, but in the case of the heart wood longitudinally along the Autumn wood. Furthermore, it will be noted that the sap wood has "taken" the creosote mostly, if not altogether, in the Autumn wood, leaving the large cells of the Spring wood unaffected.

Now suppose the medullary rays of the sap wood had consisted of a very thin layer of cells, or that those cells had been full of foodstuff and/or resin, the radial penetration of the creosote could not have taken place under the conditions of the simple straight process. Such a state of affairs exists in spruce, but not in seasoned pine. Hence it is necessary to apply torture to make spruce, fir and Douglas fir, fit for the service demanded of them. Resin must be softened, foodstuffs rendered soluble, cell membranes ruptured and taurus pads blown off their seats. But do not rely too much upon the medullary rays—make incisions!

It naturally follows from the above remarks that the best time to apply such drastic treatment to timber is as soon as felled and cut up; seasoning only tends to "case hardening," which term may be taken to cover a number of changes. As indicated throughout these pages, the removal of moisture by the Boulton process does not offer any real difficulty.

Looking back for changes or improvements in plant, one is struck by the fact that nearly all the large plants over the world are similar to those of Mr. Boulton's day. Improvements in detail there are. Cylinders are larger, pumps of better design, and provision of an overhead pressure reservoir is frequent. Recording gauges for pressure, vacuum and quantity of preservative are in common use. The lay-out of the yards is now considered

of very great importance, and the cost of grading and trackage may well exceed that of the rest of the plant. Electric power is largely used, but for the locomotives, be they tractors or cranes, steam or internal combustion is still the most convenient.

An attempt on new lines was made by Haskin, who proposed to do seasoning and preserving in one operation without altering the outward form or appearance of the timber. He employed air at high temperature and pressure, and claimed that, in addition to accelerating the ordinary seasoning effect of the atmosphere, he produced in the wood itself preservative products of the destructive distillation of the wood without permitting their escape and therefore without harm to the wood (126). On a very small scale it was possible to make an experiment at 200° Centigrade and 200 lb. pressure which fulfilled the conditions. The result was wood smelling very slightly of pyroligneous matter and otherwise in good condition. At 300° Centigrade and 300 lb. pressure the wood was destroyed. Colonel Haskin found a sufficient following in America and England to put down several plants (two in England). At least two English railways had a few sleepers treated, but when returned to them they did not appear to have the treatment which Haskin was presumed to give. In spite of an enormous expenditure in cylinders, superheaters, air compressors, etc., Haskin soon abandoned his works, and his cylinders found their way to the works of those who made normal use of them.

A most ingenious plant was designed and erected in the railway yard at Irvine by Mr. Galloway. It consisted of a "revolver" cylinder of six or more chambers operating like the firearm of that name, but differing in this, that for every phase of the revolution a tight joint was made with front and back guard-plates and connection

established with the supplies of oil, air, vacuum, etc. The only open position was for putting in the clean sleeper, which pushed out the treated one. For well-seasoned pine sleepers, the machine served very well except for trouble with the joints. In a revolution taking from three to six minutes a sleeper could be subjected to all the stages of the Rueping process, so that sleepers could be fed into and delivered from the machine at the rate of 60 to 120 per hour. For sleepers requiring prolonged treatment, at any stage, the machine was, of course, useless as an economical proposition.

A continuous dipper was proposed to give treatment equal to that of the ordinary pressure process. A very deep vessel was to be employed, and the sleepers were to be dragged to the bottom by means of a chain 'elevator' acting in the reverse direction. A cylinder 60 feet deep filled with oil would give a pressure of about 26lbs. per square inch above atmosphere. For higher pressures the plant would be inconveniently deep. For treatment with aqueous solutions which attack iron it has been proposed to construct cylinders of iron or reinforced concrete lined with a special mixture of bitumen and inert mineral matter (127). Tank and reaction vessels moulded from a mixture of hard coal-tar pitch and selected sand or gravel are now made to withstand hot solutions of sulphuric, hydrochloric and other acids. Pumps and pipes lined with glass and ebonite are in use in certain industries, so that it is possible to inject under pressure, solutions even of mercuric chloride in plant which is operated precisely as is the case with creosote and non-corrosive solutions.

The Boucherie process, mentioned by Mr. Boulton, is still worked in one or two parts of Europe for the impregnation of telegraph-poles with copper sulphate or mercuric

chloride. The lay-out of the yards with service pipes, flexible hoses and draining platforms is rather elaborate. Boucherie's helmet has been simplified down to a sort of flange clamped on to the end of the pole, which must, of course, be evenly sawn off.

A multiple plant for sleepers consists of a cylinder fitted at the end with a number of sockets to take the ends of the sleepers, which lie on cross-bars. In the door are screws to correspond with each sleeper, so that when the door is closed the opposite end of each sleeper can be forced to make a tight joint with the tapering walls of its socket. Each socket is connected with the outside by means of a pipe. When the cylinder is filled with the solution and pressure applied, the fluid is made to pass radially and longitudinally into and along the sleepers, driving before it the sap and taking its place. The outflow from the pipes connected with the sockets is examined from time to time to indicate when the preservative is passing out at full strength. The inventor published a treatise in which it was claimed that if the sap were all washed out the cellulose was practically immune to decay, but that his special solution which was substituted for the sap made preservation a certainty. He employed agar-agar and formaldehyde as his fixative for the salts of his solution.

Probably the most ingenious of the methods is worked under the title of the "Cobra Process"—a German invention (129). The machine, which is simple and portable, is in two forms, one being a hand machine little bigger than a hand hammer. The process consists in injecting a paste of water-soluble salts through a hollow needle. The hand tool is swung like a hammer or axe and the point is driven into the timber, and at the moment the blow is home a plunger in the hollow handle is given a

push by means of a lever lying along the handle under one hand of the operator. The blows are repeated at regular spacings. It is claimed that the salt dissolves in the moisture of the wood and diffuses, so that after a time the solution reaches from slit to slit. It is also claimed that poles which have begun to decay can be saved by injections above and below the ground line. A protective coat of tar or creosote over the treated zone is recommended.

Some engineers believe that it is sufficient to treat the butts of poles only so far as will give protection to the danger zone near the ground surface. So for purposes of economy it is a practice in some parts of the United States and Canada to soak the ends to the proper depth in heated creosote. An improved method is that of Pretty (130), who carries out a sort of elaborate Boucherie process by using a pipe closed at one end and fitted with a gland at the other end. This pipe is put over the end of the pole to the length desired and the gland is adjusted to make a tight joint with the pole. The vessel is connected by means of the necessary service pipes with the pumping plant, and hot creosote at any desired pressure is forced into the wood. It is obvious that after pressure vacuum may be created to withdraw oil if advisable. Where a considerable number of poles have to be treated, a battery of dipping vessels standing vertically and served by cranes or travellers is the proper lay-out.

Having given a few details of the trend of inventions and operations during the period since 1884, I should now like to turn to the work of those who have been engaged either privately or by appointment under Government Commissions in studying the causes of decay and the remedy.

Mr. Boulton took us up to the time of the great discoveries of Pasteur, and connected the decay of timber with the germ theory, which, at the time, was rather loosely applied to all sorts of diseases. Now the ordinary decay or rotting of timber, as far as is to-day known, is due solely to fungi, which may grow heads like mushrooms and toadstools or may appear as shapeless masses or network of fibres like dry rot. The bacteria and bacilli of Pasteur do not come into the picture as yet, but some day they may be found to be necessary to the economy of the fungi. It is, of course, well known that fungi propagate by means of spores which might be called germs, but once the germ finds suitable conditions for growth it propagates not itself, but a growing structure.

The fungus, having established itself upon or in a piece of timber, must produce its fruiting heads on the outside. It is the hyphæ, or filamentous processes (of which the whole fungus consists) which enter the timber, penetrate the cells, and by secreting an acid fluid cause the destruction or solution of the contents and walls of the cells. Some fungi, for example the blue sap, do not destroy the structure of the timber, but appear to be content with the material in the cells. The hyphæ in this case seem to enter by the pits.

One of the best handbooks of its kind was prepared in the form of a Paper submitted to the American Wood Preservers' Association by C. J. Humphrey, entitled "The Decay of Ties in Storage." This gives illustrations and short descriptions of fungi found on sleepers stacked for seasoning in the middle and north of U.S.A.

The British Department of Scientific and Industrial Research—Forest Products Research, has recently published a booklet entitled *Dry Rot in Wood*.

The American Wood Preservers' Association has issued

many useful Papers dealing with decay and preservation of wood. A fine work inaugurated at the request of the British Government is *Deterioration of Structures in Sea Water*, carried out under the auspices of the Institution of Civil Engineers. The American *Marine Structures: Their Preservation and Deterioration*, being the report of the Committee on Marine Piling, etc., and published by the National Research Council, Washington, D.C., is very instructive. Both these reports contain much about timber piling and, in addition, illustrations and life histories of timber's chief marine enemies. The reports of the annual meetings of the American Wood Preservers' Association, and the monthly pamphlet *Wood Preserving News* which they send out, contain much very useful information and show what enormous strides the proper treatment of timber has made in that country.

As regards the life history of some other destroyers of timber, Maeterlink's *La Vie des Termites*, apart from its speculations upon civilization in general, is a very good life history of the termites themselves. It may be supplemented by reference to Papers published by the American Wood Preservers' Association. There are other Government publications on insect attacks on timber such as that of the death-watch beetle and the lictus beetle whose activities are particularly troublesome to furniture makers.

A few pages back I mentioned that it was doubtful if bacteria played any part in the decay of timber, unless it were by way of assisting the fungi to render their food fit for consumption. There appears to be no doubt, however, that white ants, death-watch and lictus larvæ do not live entirely on raw sawdust. In the case of the beetles, it is thought that the female sees to it that a supply of wood-destroying fungus is provided at the

time of deposit of the egg or when the grub hatches out. The white ant grows its fungus on wood dust, and in its ant hill has special galleries for the purpose.

Mr. Boulton called attention to the numerous specifications for creosote differing widely each from the other. To-day, thanks to the work of individuals and societies, these are reduced to few in number, and the fads and theories of the earlier years have given place to sound common-sense views. To-day neither naphthalene nor tar acid finds itself exalted as the most essential constituent. The heavier oils are preferred, but it is understood that to obtain at a reasonable price a commercial article which is the by-product of another industry a considerable latitude in constituents must be allowed. Good results have been obtained with creosotes differing widely in their composition. The quality of coal and its method of carbonization affect the resulting tar just as much as they do the coke and gas for which the carbonization was undertaken. To-day we have more carbonization processes than ever before. By-product recovery coke ovens were in their infancy when Mr. Boulton wrote, and nearly all coke for metallurgical purposes was made in beehive ovens which burnt all the products of destructive distillation. Recovery coke ovens are now almost universal.

In the past, coke from gas-works had to be sold at very low prices in order to gain a market for the whole production. To-day coke for domestic use in open grates as well as for hot water supplies and central heating is finding its proper place. Attempts to produce a domestic smokeless fuel which would ignite easily and burn in any grate have resulted in many low temperature carbonization processes, some of which are now producing on the large scale. The exponents of these processes rely

largely upon the tar or oils they produce to help towards financial success. These low temperature oils are at the very bottom of the present-day scale as wood preservatives, but may in the end prove to be more useful than our present-day knowledge leads us to expect. They are rich in tar acids, but contain little or none of the heavy bases and heavy oils which at present are regarded as the most valuable constituents of wood preserving oils (131). The so-called neutral oils of the low temperature tar resemble those of petroleum (see earlier remarks on creosote-petroleum mixtures).

Gasworks now operate two main processes of carbonization :

(A) Horizontal retorts with full charges at high temperatures.

(B) Continuous vertical retorts.

The former produce a heavy tar of good quality, and the latter a tar somewhere between the horizontal retort product and that of the low temperature processes.

At the time Mr. Boulton wrote there was a theory amongst gas engineers that the horizontal retort could be made to yield more gas by working shallow charges at high heats with shorter periods. The result was a cracked tar rich in naphthalene and anthracene, which on distillation yielded a creosote which solidified at ordinary temperatures—a no doubt useful property in delaying bleeding from the wood, but rendering the creosote very inconvenient to use on account of the amount of heating necessary to keep the oil liquid in pipes and tanks and during the process of injection.

There were numerous gasworks, more especially in the Midlands, using a different coal and somewhat lower temperatures which produced a lighter tar, richer in tar

acids and with much less naphthalene and anthracene. So in those days there were practically only two qualities of tar, if we except some produced from those blast furnaces using a hard splint coal. To-day we have to deal with tars from horizontal retorts, vertical retorts, water-gas plants, coke ovens, blast furnaces and low temperature carbonization processes.

To return to the matter of specifications for creosoting, it soon became evident that somebody other than the theorist—be he engineer, chemist, bacteriologist or mycologist—should take a hand and try to frame a specification which, on the one hand, would provide a good preservative, and, on the other, a material which could be obtained from any producing centre without calling for an expensive preparation or curtailing the supply.

The American Wood Preservers' Association were the first to attempt to produce what might be termed a national specification, but they had to make due allowances for cheapening the oils. They dealt with the question from several points of view, that is to say, modified their specification according to the purpose for which the treated timber was to be used—sleepers, marine piling, paving blocks, etc., and in some cases admitted alternative specifications. This was with a view to cheapening the preservative by allowing certain quantities of raw tar (or topped tar) to be mixed with the distilled oil. For paving blocks, this addition of tar was probably good, but most tars contain a large quantity of "free carbon," which separates on dilution with creosote and appears as an undesirable deposit on the surface of the treated timber.

The American Railroad Engineers' Association followed with a more stringent specification, but adopted at the

same time two alternatives modelled on the specifications of the American Wood Preservers' Association.

Here in Britain we were a little slow in getting away from our cloud of specifications, but at last, in 1921 the British Engineering Standards Association was asked to take the matter in hand. A panel was formed of engineers and chemists of railways, Government and municipal departments and producers. After meetings and investigations a general specification, together with methods of testing, was evolved. At one stage, representatives of Scotch producers agreed that the specification was good, but that practically none of the Scotch creosote would comply with certain of its requirements. Yet their oil had always satisfactorily preserved the sleepers of the Scotch railways. An exception had to be made for Scotch oil, not in the body of the specification, but as an appendix thereto. The British Standard Specification is now adopted by all bodies at home, and in many of the European countries, and has been added to the older ones in Appendix E.

The official publications may be obtained from the headquarters of the various bodies, or information on any point will gladly be given by the British Wood Preserving Association—a society recently formed for the express purpose of aiding the study and practice of wood preservation.

Before closing, I should like to add a few words as to a very large class of timber users whose substance is being wasted by fungi and insects. Thanks to the advertisements and propaganda in connection with proprietary wood preservatives, the knowledge of the material saving to be effected by the use of preservatives has become more widespread. Unfortunately many either do not know where to look for decay or where the treatment

should be applied. Others do not think it worth while to go to the little extra trouble and expense. Farmers use many stakes cut from spinneys on their property or from local woods. After three years these may begin to break off, and by the end of five years will probably all be gone at the earth line. Many will be rotten at other parts through beetle and fungus owing to the bark being left on. If questioned the farmer would probably reply that the stakes have lasted as long as he wanted them or that he can easily cut some more. Such an attitude is economically unsound in these days of high labour costs. The big hop-growers know the value of treating the ends of their poles, and have simple fire-heated dipping tanks for the purpose; but what about the small holder? As I write I can look at a boarded fence recently blown over. This fence was erected in 1924. The posts are broken at the earth-line, yet the owner spent time in painting that fence with a proprietary article which was quite a good preservative. He did not treat the part that really mattered. Had he spent the time and preservative in treating the fence about the earth and air line it would have been standing to-day and for many years to come. Of course the ideal proceeding would have been to have had the posts impregnated by pressure treatment before erection. In contrast to the above is a post and rail fence creosoted before section in 1880 and still standing. Half of this fence was no longer required where it was originally erected, and was used elsewhere on the estate.

There is no country in the world where wood preservation should not be a vital industry, and gradually the practice is spreading. North America can to-day say that wherever there are railways there are timber-treating plants, and no country seems to have done more

to propagate the gospel of wood preservation. India has awakened, Australia and New Zealand also.

It is interesting to note that hard woods of a size suitable for poles such as ironbark and stringy bark are subject to decay in the untreated state, but can be made to take creosote into the sap wood almost as easily as in the case of pine and similar soft woods.

In some countries where hard wood was difficult to obtain locally, imported creosoted softwoods were and are being used. A better knowledge of the possibilities of the use of treated local softwoods is gradually spreading.

Whilst the timber preserver is showing what he can do to arrest decay and increase mechanical resistance, the engineer has been studying the prevention of undue stress and wear and tear. With heavier rolling stock and greater speeds, he asks more from his sleepers and gets it. In the first place, he has all boring and cutting done before creosoting, and in the second, if he uses chairs, he bolts or screws them down by powerful machinery. In some cases he uses a felt pad between the wood and the iron. If he uses flanged rails, he now, if wise, has a flat steel plate between rail-bottom and sleeper, such plate serving to spread the load and reduce the cutting into the wood. Screw brobs have replaced the old spikes. In telegraph-poles and marine piling the engineer knows that if he has to do any cutting he must thoroughly dress the places with hot creosote.

In the opinion of many the mining engineer in this country has neglected his opportunities of saving much expense in the replacement of timbers used in permanent galleries, but there are signs that more attention is now being given to the preservative treatment of such timbers. For those who object to creosote there are the metallic salt preparations, some of which are finding considerable

use in Germany. Coal mines there, either singly or in groups, have their impregnation plants, and use chiefly metallic salts, but examples of creosoting by the Rueping process are common. The objection to creosote on account of the smell being apt to mask other warning smells of gas may under certain conditions be sound, but the fear of ignition is unfounded since a creosoted post is less easily fired than an untreated one of rough wood and will take longer to burn through. The reason is that creosoted wood offers fewer ignition points in the form of splinters and raised grain, and when alight the destruction is confined to the surface, the evaporation of the oil keeping the interior cool and maintaining an atmosphere free from oxygen at the surface. Some peculiar effects have been noticed in sleepers treated with sodium fluoride used on an electric railroad near the sea and liable to some flooding with calcareous water. The return current earthed through the rails and sleepers caused a substitution of calcium for sodium in the preservative, and presumably rendered it ineffective.

In writing of wood preservation, one should not forget the destroyer—fire. There have been many disastrous fires which might not have occurred if the woodwork of some room had been “fireproofed.” The term is wrong, because no wood could be so treated as to render it indestructible by great heat. Fire-resisting would be a better term. There have been many attempts to impregnate wood with some compound which would prevent ignition and delay the spread of flame (132). A metallic salt containing much water of crystallization would act at first by giving off steam, but one which will melt at a low temperature and coat the fibres with a sort of oxygen-proof enamel seems to be more effective. The use of others which not only melt, but give off some

incombustible gas such as ammonia or chlorine, is the basis of many patented processes, several of which are in actual use. It might be as well to warn would-be fireproofers that some metallic salts in crystallizing from solution are apt to disrupt the fibre, and this may have been the case with the piece of timber exhibited by Mr. Boulton as having been treated by a solution of sulphate of soda. The separation into rings may have been due to the fact, mentioned earlier in this Paper, that liquids are absorbed mostly in the autumn wood.

It is often desired to treat wood to make it fit for use as tanks, stirrers, flooring and benching in chemical works and laboratories. Ordinary paint and varnish are easily removed by alkalis, and even by acids, so some other protective must be sought. Paraffin wax, when melted, becomes a limpid liquid and can be injected into preheated wood as easily as creosote. The wax is proof against most chemicals and renders the wood "waterproof." Montan wax (a product of lignite) behaves similarly to paraffin wax, but is not so proof against some chemicals, and is more difficult to apply on account of its higher melting-point and low solubility in oils at ordinary temperatures.

Coolidge in the United States claims the treatment of wood with montan wax as his process, and indicates its use with creosote as being a much better and more lasting thickener than naphthalene (133).

I would like to add here a note about naphthalene and the thickening of creosote. There still seem to be two schools of thought in the timber preserving world—the purely antiseptic and the antiseptic-physical. In the case of creosote the former is represented by the followers of the comparatively new empty-cell process, who cannot logically advocate the use of

creosote supersaturated with naphthalene. Nor should the full-cell people be too slavishly keen. They may still say "Give us, if you can, something which will keep all the oil in the wood." It sounds a good prayer, and it would be good in reality if the whole timber were fully impregnated. But in dry weather the wood may begin to check and expose depths where the preservative has not penetrated. There may be spots where a pocket of moisture or a patch of blue-sap fungus has inhibited the entry of creosote. The full-cell treatment will provide a reserve to save such undefended spots only if the oil be mobile, but not if fixed by being solid. It may be advanced, however, on behalf of the naphthalene enthusiasts that naphthalene in separating from creosote does so in crystals and not as a jelly. The crystals may delay the draining if such could otherwise take place, but they will not stop it.

In concluding this rather meagre summary of the happenings in the timber preserving world, I feel I cannot do better than take a few passages from the Paper I presented to the International Forestry Congress held in Rome in 1896.

"Returning to the question of cost, it may be a very short-sighted policy to act upon the idea that a given quantity or quality of preservative is too dear. The preservative treatment may cost as much as the wood and yet be economical to use in the case of sleepers. Four times the life at twice the initial cost seems to be a sound business proposition, but is this the only saving? What of the cost of replacement in position and the extra strain and damage to the other members? How many derailments have been directly due to failure of sleepers?

"It would appear to be a sound proposition to reduce the quantity of preservative where such preservative has been known to confer immunity from decay for a longer period than the useful life of the timber.

"We hear of telegraph-poles which after 30 or 40 years of service are too small to carry the number of wires now required on that circuit, and of railway sleepers which have been hammered and split until they can no longer support the rail. In face of such facts it is difficult to refuse the engineers' appeal for cheaper treatment which will preserve the timber from rot just so long as it remains useful.

"Again the warning must be issued to the engineer: 'Do not cut your treatment until you know how to draw the line between the mechanical and the "preserved" life.' In my opinion there can be no narrow boundary.

"It is necessary also to provide that the preservative shall be there in an active state until the end."

I wish to thank my colleagues, Captain China and Mr. Forbes, for their valuable co-operation, and Sir Harold Boulton, who, as editor, has not only curtailed my tendency to occupy too much space, but has helped me with many suggestions. Having thus shifted the blame for having left many important things unsaid, I take farewell of my readers, with the hope that they and their timber may be preserved for a long time to come.

HUBERT FERGUSON.

CONCLUDING REMARKS

BY

THE EDITOR

CONCLUDING REMARKS

I THINK I CANNOT DO BETTER than to mention, in concluding this collection of material connected with wood preserving in the last one hundred years, a very interesting work¹ which covers the same field in the continent of America. It is a publication recently issued in the name of the American Wood Preservers' Association, by Mr. A. L. Kuehn, the President of the American Creosoting Company.

It is interesting because the earlier part covers almost exactly the same ground as that covered by the earlier part of this publication, and the latter part, which deals, roughly speaking, with the American developments of wood preserving in the present century, makes instructive reading on more or less parallel lines in conjunction with the developments on this side of the Atlantic for the last thirty years.

The volume has as a sub-heading, the names "Bethell," "Boulton," "Chanute," the third name being identified with a separate history of the American wood preservation, since it had a separate history.

Among the points on which additional information can be added to the European knowledge of wood preservation is the fact that very valuable particulars are given as to the treatment of a large variety of different woods on the American continent which have not been the subject of so much detailed experiment on this side of the water. There are also some very valuable statistics of creosoting results collected from European continental countries. There are three points to be noticed in the creosote specifications—firstly, that a fairly large mixture of crude tar is the recognized practice; secondly, that crude petroleum oils are recognized as a legitimate addition to coal-tar creosote, and, thirdly, that it has been

¹ *Pioneer Work in Modern Wood Preservation—Bethell, Boulton Chanute.* Commemorating the twenty-fifth Anniversary of the founding of the American Creosoting Company.

the practice of American railway engineers to resort to treatment by chloride of zinc, especially for dry zones, when the price of creosote reaches a certain point.

I would certainly recommend the perusal of this American volume to those who take sufficient interest in the matter to have read the present compilation.

As an instance of the continuing value of the work done by the American Wood Preservers' Association, I would also mention a pamphlet recently issued under the title of *Comparative Efficiencies for Timber*, by F. H. Rhodes and F. T. Gardner. There is no doubt that close touch with the older American Society will be of immense value to the younger one on this side, which may in its turn hope before very long to repay the debt in kind.

In conclusion, while it will be seen that great strides have been made in the science of Wood Preservation during the last hundred years, especially as applied to outdoor timber such as Railway Sleepers, Poles, Fencing, Bridge Timber and Marine Piling, there is no doubt that a good deal of work still has to be accomplished in the extension of preservative treatment to all kinds of woodwork employed inside buildings where preservatives in exactly the same form as for outside work are not feasible.

This field for future enquiry embraces not only prevention of deterioration from moisture, dry rot, attacks from fungoid growths and living organisms, but the all important department of fire proofing.

We are by no means at the end of our tether in our studies as to how to render most suitable for every sort of work in fair and honest competition with concrete, steel and other materials, that material which is the most amenable and adaptable known to mankind for an infinite variety of purposes, namely Wood.

Like Mr. Fergusson, I have to thank Captain China and Mr. Walter Forbes for their valuable assistance in compiling this volume.

APPENDICES

APPENDIX A

A.D. 1838—No. 7731

Rendering Wood, Cork, and Other Articles more Durable, etc.

BETHELL'S SPECIFICATION

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, John Bethell, of Mecklenburgh Square, in the County of Middlesex, Gentleman, send greeting.

WHEREAS Her present most Excellent Majesty Queen Victoria the First, by Her Royal Letters Patent under the Great Seal of Great Britain, bearing date at Westminster, the Eleventh day of July, in the second year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said John Bethell, Her especial licence, full power, sole privilege, and authority, that I, the said John Bethell, my executors, administrators, and assigns, or such others as I, the said John Bethell, my executors, administrators, or assigns, shall at any time agree with, and no others, from time to time and at all times during the terms of years therein mentioned, should and lawfully might make, exercise, and vend, within England, Wales, and the Town of Berwick-upon-Tweed, and also in all Her said Majesty's Colonies and Plantations abroad, my Invention of "IMPROVEMENT IN RENDERING WOOD, CORK, LEATHER, WOVEN and FELTED FABRICS, ROPES and CORDAGE, STONE and PLASTERS or COMPOSITIONS, EITHER MORE DURABLE, LESS PERVIOUS TO WATER, or LESS INFLAMMABLE, AS MAY BE REQUIRED FOR VARIOUS USEFUL PURPOSES;" in which said Letters Patent is contained a proviso obliging me, the said John Bethell, by an instrument in writing under my hand and seal, particularly to describe and ascertain the nature of my said invention, and in what manner the same is to be performed, to be enrolled in Her said Majesty's High Court of Chancery within six calendar months next and immediately after the date of the said in part recited Letters Patent, as in and by the same, reference being thereunto had, will more fully and at large appear.

NOW KNOW YE, that in compliance with the said proviso, I, the said John Bethell, do hereby declare that the nature of my said Invention, and in what manner the same is to be performed,

is particularly described and ascertained in and by the following description thereof ; that is to say :

My Invention of Improvements in Rendering Wood, Cork, Leather, Woven and Felted Fabrics, Ropes and Cordage, Stone and Plaster or Compositions, either more Durable, or less Pervious to Water, or less inflammable, as may be required for various Useful Purposes, consists in more perfectly impregnating such articles, in manner herein-after described, with various mixtures or solutions herein-after mentioned, so that they may be saturated throughout with such mixtures and solutions, whereby they are rendered either more durable, less pervious to water, or less inflammable, according to the different mixture or solution with which they were impregnated. To explain my Invention more clearly, and to show how it is carried into effect, I will, first, describe the various forms of apparatus or means for more thoroughly impregnating the articles with the mixtures and solutions ; then, secondly, the mixtures or solutions ; and, thirdly, state with what mixtures or solutions each description of article is to be impregnated, as aforesaid, to render it either more durable, less pervious to water, or less inflammable, as may be required for various useful purposes.

First, as to the various apparatus or means for more thoroughly impregnating the above-named articles with the mixtures or solutions herein-after described. These forms of apparatus are constructed for the purpose of forcing the various mixtures or solutions herein-after named into the interior of the above-named articles, either by means of hydrostatic or pneumatic pressure aided in some cases by exhausting the pores of the articles of the atmospheric air contained therein ; or by boiling the articles in vacuo, or, as to wood, by placing the butt ends of trees, immediately after they are felled, in vessels containing solutions of the first class herein-after described, so that the solutions may circulate with the sap throughout the interior of the tree, and thus thoroughly impregnate the wood. The various apparatus I will now describe. An air and watertight vessel or tank must be made of strong metal, of any form that may be preferred (one made like the circular wrought-iron boilers for high-pressure steam engines answers very well), strong enough to withstand an internal pressure of 200 lbs. to the square inch, having a lid or door to it which is made to screw on air-tight. The tank is fitted on the top with a common steam-boiler safety valve, and it is connected by one pipe having a stop cock or valve in it with an exhausting air-pump, and by another pipe likewise fitted with a stop-cock with a pump for forcing liquid into the tank made like the pump for forcing water into the hydrostatic presses. This form of apparatus is well known and can be made by any engineer. The articles to be impregnated are put into the tank and the lid screwed on airtight, the cocks in the pipes leading to the pumps being shut ; the tank is then filled with the desired mixture or

solution through a pipe having a stop cock in it which is then shut and the cock in the pipe leading to the airpump being opened, that pump is set to work for the purpose of exhausting or drawing the air out of the tank, and also out of the pores of the various articles, after which the liquid, mixture or solution will penetrate into and fill up those pores before occupied by the air, more particularly if the tank is kept heated, which may be done in any convenient manner. But for some articles this may not be found sufficient, and in such cases the air pump, after having exhausted the tank is stopped, the cock or valve shut, and the liquid force pump set to work (its cock being previously opened) to force some of the same mixture or solution into the tank until the required degree of pressure is obtained. The working of the liquid forcing pump must be repeated every one or two hours, as the articles, by absorbing the mixture or solution cause the pressure to diminish. The degree of pressure to which it is determined to work up to is regulated by loading the safety valve with the appropriate weights, and as soon as the pressure of the condensed liquid exceeds the weight in the valve the liquid is forced out of the valve, and the pressure within reduced. In impregnating wood by this apparatus I have found that the process is much expedited by placing the logs of wood in the tank in a perpendicular or slanting position, so that the butt end of the logs may be at the bottom of the tank, and their upper ends a little above the surface of the liquid. In this case, as soon as the exhausting process is commenced with the air pump, the air travels freely up the longitudinal pores of the wood, and the liquid follows it, entering into such pores at the bottom or butt end of the log and following the air as it is drawn out of them at the top by the air pump. It may not be necessary with some very porous articles to use both the processes of exhausting the tank of air by the air pump and forcing in the liquid by the hydrostatic force pump but either one or the other of the processes as is most convenient may be used, and will be found to impregnate the articles sufficiently. The form of apparatus above described is that which I prefer using but it is evident that the pressing or forcing the liquid mixtures or solutions into the articles by means of pneumatic or hydrostatic pressure may be obtained in various other modes, some of which I will mention. Steam at very high pressure may be let into the tank through a pipe over the surface of the liquid within, thereby pressing on it with considerable force; or condensed air may be pumped in for the same purpose or an hydrostatic force may be obtained in the closed tank by connecting it by means of a pipe having a stop cock in it with a cistern placed at a considerable height above the level of the tank, when upon the cock being opened the pressure of the liquid through the pipe from the elevated cistern will be increased in the tank in proportion to the altitude of the cistern over the tank. Another mode of impregnating wood is by means of bags made of

sheet caoutchouc or air and water-proof cloth large enough to hold about two gallons, which are made open at one end into which the butt ends of the pieces of wood are placed, and the edges of the bags tied very firm and close to the pieces of wood by means of small lines wound several times round the outside edges of the bags over the pieces of wood, and to the other ends of the bags are fitted small pipes furnished with stop cocks which proceed either to an elevated cistern containing the liquid with which it is desired to impregnate the wood as above described or else to a liquid forcing pump as above mentioned. When the cock in the pipe is opened the liquid in the cistern, by its greater altitude, will force its way into the pores of the wood, or when the pipe is connected with the pump the hydrostatic pressure caused by the pump when worked will force the liquid into the pores of the wood. One cistern or pump will thus be sufficient to impregnate many pieces of wood at once. Trees that have been just cut down may be rapidly impregnated in this manner, and many such new fallen trees will be thoroughly impregnated in a few days with the solutions of the first class hereafter mentioned, by merely placing the butt ends in troughs or open tanks filled with the solutions which will circulate with the sap throughout the whole tree. Skins of leather and fabrics of any kind may be impregnated in a similar manner by sewing them together in the form of bags, having pipes leading to an elevated cistern or pump, as above described, through which the solutions or mixtures may be forced into the bags and through every pore of the skins or fabrics. Pipes made of leather or of folds of thick canvas can in this manner be made less pervious to water with the mixtures or solutions hereafter mentioned for that purpose, by closing one end of the pipes and forcing the liquid mixtures in at the other end. Any of the articles may also be impregnated by placing them in the tank above described, exhausting the air thereout by the air pump, and then applying heat in any convenient manner to the tank until the solution or mixture therein is made to boil, which is commonly called boiling in vacuo.

Secondly, as to the mixtures or solutions to be used with either of the above forms of apparatus for impregnating the various articles. To describe these more clearly I have divided them into three classes, the first class containing such as are applicable to render certain of the articles above-named more durable; the second class, such as will render all the above-named articles more durable and less pervious to water; and the third class, such as will render them less inflammable.

THE FIRST CLASS

Number 1. Solution of Sulphate of Iron. One pound of the salt to be dissolved in two or three gallons of water and to be

used as soon as dissolved, or the pyroligneous iron liquor used by dyers mixed with about half its quantity of water.

2. Sulphate of Copper. One Pound of the salt dissolved in three or four gallons of water.

3. The waters of Copper Mines, and also the waters of streams or brooks in a copper country which contains copper suspended in solution in them.

4. Chloride or Chlorate of Copper. One Pound dissolved in four gallons of water.

5. The Yellow Chromate of Potash. One pound dissolved in four gallons of water.

6. Refuse lime water from gas works. The liquor must be allowed to rest for several days until the lime is precipitated to the bottom, when the supernatant liquor may be drawn off and used to impregnate wood.

I would here remark, that I prefer that the solution of chromate of potash and of the refuse lime liquor of the gas works should be forced into the pores of the wood in manner above mentioned, but I do not mean to confine myself to the mere impregnating the wood therewith in such manner; but I do claim the use of chromate of potash and of the said refuse lime liquor in any manner that may be preferred, for the purpose of rendering wood more durable, as part of this my Invention.

THE SECOND CLASS

Number 7. Any mineral tar or bitumen, or any vegetable tar mixed, when necessary so to do, with any volatile oil or spirit to thin it sufficiently to penetrate the articles on which it is to be used, and to which may be added a portion of caoutchouc or black rosin, which is incorporated therewith by heat.

8. Coal Tar obtained from gas works, thinned with from one-third to one-half of its quantity with the essential oil or spirit obtained by the distillation of coal tar. That which I use is the common spirit left after the naptha is obtained, and commonly called in the Trade "dead oil." Either caoutchouc or rosin may be added to this mixture if required, by dissolving the caoutchouc or rosin in the coal tar and oil by heat, or by adding the well-known caoutchouc paste or varnish to the tar and oil, heating the mixture and stirring it well until the caoutchouc is thoroughly mixed with the tar. From one-quarter to half a pound of caoutchouc, or half pound of black rosin to one gallon of tar and oil, may be used; but it will be necessary that more of the dead oil should be added to thin it sufficiently to penetrate the wood, etc. The foreign bitumens or asphaltes may be used instead of the coal tar, but they will require a greater proportion of deal oil or other volatile oil to thin them sufficiently.

9. Vegetable tar, as Archangel or Stockholm. These tars

HP

contain an acid which is injurious, and therefore before using them free them from it by agitating them for some time with lime water, or by throwing into the tubs or vessels in which the tar stands a quantity of old rusty iron or iron slag, and this prepared tar is then mixed with the above-named dead oil ; or with the spirit distilled from itself ; but I prefer the dead oil, as it is cheaper. Caoutchouc or rosin may be added thereto if desired, in manner described in No. 8.

Number 10. Whale oil, codfish oil, or any other fish oil, mixed with from one-third to one-half of dead oil.

11. The same as Number 10, with the addition of sulphur, as three ounces of sulphur dissolved by heat in every gallon of the mixture, Number 10.

12. Boiled or drying linseed oil mixed with oil or spirits of turpentine.

13. Boiled or drying linseed oil, to which caout. paste is added, as about one-half pound of caout. paste to every gallon of linseed oil.

14. Rape oil in which caout. is mixed as in Number 13.

15. Solutions of caout. in spirits of naphtha or turpentine, or any other spirits.

16. Beeswax dissolved in spirits of turpentine, as about one pound of wax dissolved in one gallon of spirits of turpentine.

THE THIRD CLASS

Number 17. Soluble glass dissolved in water, in the proportion of one pound to five or six gallons of boiling water (soluble glass is well-known, and the mode of making it is fully described in several chemical and other books).

18. Four pounds of alum, eight pounds of potash or soda, two pounds of borax, and four ounces of glue or starch dissolved in twenty gallons of warm or boiling water ; the articles to be dissolved in the water in the order in which they are named. In describing the solutions and mixtures above named, I have given the proportions of the ingredients composing the distinct solutions and mixtures, and also the separate solutions and mixtures which I have found to answer best, but I do not mean to confine myself to these proportions, or to the use of these solutions or mixtures separately, because the ingredients composing each solution and mixture may be mixed in different proportions, and several of these solutions or mixtures may be combined with each other, in order to produce the desired effects.

Thirdly, as to the different mixtures or solutions with which the different articles are to be impregnated. Wood may be impregnated in manner above mentioned with either of the solutions No. 1, 2, 3, 4, 5, 6, of the first class, to render it more durable. When No. 1 is used, and it is intended to place the wood where

it will be exposed to the weather, I recommend that the wood be painted or tarred over, which will not be necessary when placed in the interior of a house, or under cover. To render wood more durable, and less pervious to water, I use any or either of the mixtures No. 7, 8, 9, 10, 11, 12, or 13, of the second class, according to the different purpose to which the wood is to be applied. The mixtures No. 7, 8, 9, 10, or 11, are chiefly applicable to wood that is much exposed to the weather, as for railroad sleepers, piles, out-door posts and fences, etc. etc. For wood intended to be polished I use No. 12, which peculiarly fits it to take a high polish; and for wood that it is desirable to render tough, such as carriage wheels, frames of machines, etc. etc., I use No. 13. The mode of impregnating wood by means of bags, as above described, or new-fallen trees, by the circulation of the sap, is not applicable to impregnating wood with either of these last-named solutions of the second class, but in such cases the wood must be impregnated in the tank in manner above mentioned. Cork may be rendered more durable and less pervious to water by impregnating it in manner above mentioned with several of the solutions above named, but I prefer using either No. 12, 13, 14, or 15, either I impregnate in manner above mentioned with either of the mixtures No. 12, 13, 14, 15, or 16, of the second class respectively, to render it more durable and less pervious to water. In this manner boots and shoes may be rendered less pervious to water after they are made. To render woven and felted fabrics, including paper, more durable and less pervious to water, I impregnate them in manner above named with either of the mixtures No. 12, 13, 14, 15 or 16, and besides these, canvass may be impregnated with either of the solutions No. 2, 3, or 4, to render it more durable. To render ropes and cordage more durable and less pervious to water, I impregnate them in manner above mentioned with either of the mixtures No. 12, 13, 14, or 15. All descriptions of porous stones, such as Portland stone, freestone, chalk, some marbles, and plaster of Paris, or such compositions as are made with burnt clay, or with plaster of Paris and cements in imitation of plaster or stone, are to be impregnated in manner above named with the solutions No. 1, 2, or 3, of the First Class to render them more durable, and with either of the mixtures of the Second Class to render them more durable and less pervious to water. For Portland stone, freestone, chalk or any other porous stone, No. 8, 9, 10, or 11, may be used. Statues or architectural ornaments made of Portland stone or freestone when impregnated with these mixtures will become infinitely more durable, and if the colour is objected to, they can be afterwards painted or coloured in any colour that is desired; marble ornaments or statues when impregnated with either of the mixtures No. 11, 12, 13, 14, 15, or 16, will resist the injury generally caused by exposure to the weather, and become more durable and less pervious to water, which, congealing in its pores

by the frost, causes it frequently to crumble away. Statues or ornaments made of plaster of Paris, or with the compositions above mentioned, must be impregnated with either No. 1, 2, and 3 of the First Class, or with either No. 10, 11, 12, 13, 14, 15, or 16, of the Second Class. Bricks impregnated with either No. 7, 8, or 9, would be very durable and less pervious to water, and useful for many purposes, particularly for building foundations of houses or cellars in damp situations, or for paving the streets, the joints being made with asphalte or bituminous matter instead of common lime mortar. All the articles above named may be rendered less inflammable by impregnating them in manner above described with either of the solutions of the Third Class, No. 17. or 18.

In witness whereof, I, the said I, John Bethell, have hereunto set my hand and seal, this Eleventh day of January, in the year of the Lord One thousand eight hundred and thirty-nine.

JNo. (L.S.) BETHELL.

AND BE IT REMEMBERED, that on the Eleventh Day of January, in the second year of the reign of Her Majesty Queen Victoria, the said John Bethell came before our said Lady the Queen in Her Chancery, and acknowledged the Instrument aforesaid, and all and every thing therein contained and specified, in form above written. And also the Instrument aforesaid was stamped according to the tenor of the Statute made in the fifty-fifth year of the reign of His late Majesty King George the Third.

Inrolled the Eleventh day of January, One thousand eight hundred and thirty-nine.

APPENDIX B

A.D. 1879, 15th May—No 1954

Treating Timber

LETTERS PATENT to Samuel Bagster Boulton, of No. 64, Cannon Street, in the City of London, for the Invention of "IMPROVEMENTS IN TREATING TIMBER WITH ANTISEPTIC OR PRESERVATIVE FLUIDS."

Sealed the 12th August 1879, and dated the 15th May 1879.

PROVISIONAL SPECIFICATION left by the said Samuel Bagster Boulton at the Office of the Commissioners of Patents on the 15th May 1879.

SAMUEL BAGSTER BOULTON, of No. 64, Cannon Street, in the City of London. "IMPROVEMENTS IN TREATING TIMBER WITH ANTISEPTIC OR PRESERVATIVE FLUIDS."

In treating timber with antiseptic or preservative fluids, such as the heavy oils of tar, commonly called creosote, or other oily or bituminous liquids, it is of importance that before such fluid is forced into the timber the latter should be freed as much as possible from all moisture, such as sap and watery particles contained in its cells, and in order to effect this it has heretofore been necessary either to stack the timber for a considerable length of time in the open air, or to adopt various artificial methods of dessication, which last have been found to be open to many practical objections.

My present Invention has for its object to obviate the loss of time, and also the labour, expenses, and other inconveniences attendant upon drying the timber by the methods above described before subjecting it to the action of the creosote, and also to enable a greater amount of moisture to be expelled from the timber than can be extracted by lengthened drying in the open air, so as to ensure its more perfect saturation with the creosote. Any convenient form of apparatus may be used for the process I am about to describe, but I generally make use of the well known pressure tank or cylinder and apparatus, but with the modifications hereinafter described. The timber having been introduced into the cylinder, which is then hermetically closed, a communication may be open with the air pump, and a sufficient vacuum may be produced in the usual way in order to facilitate the entry of the creosote into the cylinder, but this

preliminary vacuum is not necessary to my process. The creosote being introduced into the cylinder, I take advantage of the fact that the creosote or other heavy oil has a much higher point of ebullition and evaporation than the boiling point of water, and I therefore heat the creosote to a much higher degree than has heretofore been applied in such pressure cylinder, and by preference to a temperature higher than that of boiling water, and sometimes as high as 300° Fahr. or higher. The timber being subjected to this high rate of temperature the watery particles contained in it will become evaporated, and I draw them off by means of an air pump which communicates by a pipe or pipes with one or more air chambers situated on the top of the cylinder. A condenser or worm is interposed between the said air chamber and the air pump so that the steam and any oily particles which may accompany it are condensed, and the latter may be separated and recovered.

It will thus be seen that by my above described Invention the watery particles contained in the timber are subjected to a process of distillation by the heat of the creosote in which it is submerged, assisted by the action of the air pump and condenser, and the cells of the wood being expanded by the heat and the escape of vapour become better adapted for the reception of the antiseptic fluid, which enters the timber and takes the place of the evacuated moisture. If a very high degree of temperature be applied a large quantity of creosote will be found to have been absorbed by the wood, so that the process may in certain cases end here, or it may be supplemented by forcing in further quantities of creosote by the action of the force pump, according to the well known method. It will be seen that by the above process I am enabled to treat the wood while still green or saturated with sap or moisture, and in the case of floated timber to take it direct from the water and to effect the perfect removal of such moisture and the saturation with creosote in one and the same vessel in a comparatively short space of time, and in a more perfect manner than heretofore.

The heating of the creosote may be effected either by steam pipes inside the creosoting vessel, or by fire heat applied externally thereto, or the creosote may be heated to the required degree before being introduced into the cylinder.

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said Samuel Bagster Boulton in the Great Seal Patent Office on the 14th November 1879.

SAMUEL BAGSTER BOULTON, of No. 64, Cannon Street, in the City of London. "IMPROVEMENTS IN TREATING TIMBER WITH ANTISEPTIC OR PRESERVATIVE FLUIDS."

In treating timber with antiseptic or preservative fluids, such as the heavy oils of tar, commonly called creosote, or other oily

or bituminous liquids, it is of importance that before such fluid is forced into the timber the latter should be freed as much as possible from all moisture, such as sap and watery particles contained in its cells, and in order to effect this it has heretofore been necessary either to stack the timber for a considerable length of time in the open air, or to adopt various artificial methods of dessication, which last have been found to be open to many practical objections.

My present Invention has for its object to obviate the loss of time, and also the labour and expense, and other inconveniences attendant upon drying the timber by the methods above described before subjecting it to the action of the creosote, and also to enable a greater amount of moisture to be expelled from the timber than can be extracted by lengthened drying in the open air, so as to ensure its more perfect saturation with the creosote. Any convenient form of apparatus may be used for the process I am about to describe, but I generally make use of the well known pressure tank or cylinder and apparatus, but with the modifications hereafter described. The timber having been introduced into the cylinder, which is then hermetically closed, a communication is opened with the air pump, and a sufficient vacuum may be produced in the usual way in order to facilitate the entry of the creosote into the cylinder, but this preliminary vacuum is not necessary to my process. The creosote being introduced into the cylinder I take advantage of the fact that the creosote or other heavy oil has a much higher point of ebullition and evaporation than the boiling point of water, and I therefore heat the creosote to a much higher degree than has hitherto been usually applied in such pressure cylinder under the ordinary process, and by preference to a temperature higher than that of boiling water, and sometimes as high as from 250° to 350° Fahr. or higher. The timber being subjected to this high rate of temperature the watery particles contained in it will become evaporated, and I draw them off by means of an air pump which communicates by a pipe or pipes with one or more air chambers situated on the top of the cylinder. A condenser or worm is interposed between the said air chamber and the air pump so that the steam and any oily particles which may accompany it are condensed, and the latter may be separated and recovered. It will thus be seen that by my above described Invention the watery particles contained in the timber are subjected to a process of distillation by the heat of the creosote in which it is submerged, assisted by the action of the air pump and condenser, and the cells of the wood being expanded by the heat and the escape of vapour become better adapted for the reception of the antiseptic fluid which enters the timber and takes the place of the evacuated moisture. If a very high degree of temperature be applied a large quantity of creosote will be found to have been absorbed by the wood, so that the process may in

certain cases end here, or it may be supplemented by forcing in further quantities of creosote by the action of the force pump according to the well known method. Or this second part of the process may be carried out and the supplemental quantity of creosote forced into the wood by substituting for the action of the ordinary force pump the pressure of steam, gas, or compressed air, as pointed out in the Specification to my Patent of 16th March 1865, No. 734. It will be seen that by the above process I am enabled to treat the wood while still green or saturated with sap or moisture, and in the case of floated timber to take it direct from the water and to effect the removal of such moisture and the saturation with creosote in one and the same vessel in a comparatively short space of time, and in a more perfect manner than heretofore.

The heating of the creosote may be effected either by steam pipes inside the creosoting vessel, or by fire heat applied externally thereto, or the creosote may be heated to the required degree before being introduced into the cylinder.

I claim in respect of the treatment of wood by antiseptic or preservative fluids,—

First. The method herein described of distilling or expelling the watery particles from the wood inside closed vessels by means of the highly heated creosote or other liquid with which the wood is to be impregnated, the resulting steam and other vapours being exhausted from the vessel and condensed as they are generated.

Second. The method herein described of distilling or expelling the watery particles from the wood inside closed vessels by means of the highly heated creosote or other liquid with which the wood is to be impregnated, the resulting steam and other vapours being exhausted from the vessel and condensed as they are generated, and the wood being subjected to pressure in the same vessel after completion of such distillation in order to cause the more perfect penetration of the liquid into the cells.

In witness whereof, I, the said Samuel Bagster Boulton, have hereunto set my hand and seal, this Fourth day of November, in the year of our Lord One thousand eight hundred and seventy nine.

S. B. BOULTON. (L.S.)

APPENDIX C

(Amended 1930)

DISTINCTIVE PROPERTIES OF VARIOUS COAL-TAR PRODUCTS

NAME	FORMULA	Sp. Gr.	Boiling Point Fahrenheit	Melting Point Fahrenheit
			°	°
Benzol	C_6H_6	0.883	176.7	—
Toluol	C_7H_8	0.871	231.8	—
Xylol	C_8H_{10}	0.865	280-287	—
Cumol (pseudocumene)	C_9H_{12}	0.888	336.2	—
Pyridine	C_5H_5N	0.989	240	—
Carbolic acid (phenol or acide phénique) ¹	C_6H_6O	1.080	359.6	108.5
Cresylic acid or cresol	C_7H_8O	1.040	375-397	—
Naphthalene	$C_{10}H_8$	1.152	424.4	174.2
Leucoline or quinoline	C_9H_7N	1.098	462.2	—
Cryptidine	$C_{11}H_{11}N$	—	525	—
Phenanthrene	$C_{14}H_{10}$	—	644	204-212
Carbazol	$C_{12}H_9N$	—	671	460.4
Anthracene or para- naphthalene	$C_{14}H_{10}$	—	663.8	421.7
Acridine	$C_{13}H_9N$	—	Over 680	230
Pyrene	$C_{16}H_{10}$	—	Over 680	298.4
Chrysene	$C_{18}H_{12}$	—	816.8	482
Benzerythrene	$C_{24}H_{18}$	—	—	586.4

¹ In French specifications the term acide-phénique is usually applied to all tar acids which are removable by the caustic alkali tests.

APPENDIX D

PROPERTIES OF SUBSTANCES NOT DERIVED FROM COAL-TAR.

Name				Sp. Gr. at 60° Fahr.	Sp. Gr. at 100° Fahr.	Boiling or Decomposing Point, Fahrenheit.	Melting Point, Fahr.
						°	°
Bone oil	..	..	..	0.946	—	350	—
Olive oil	..	..	..	0.915	—	600	—
Palm oil	..	..	..	—	0.890	above 600	80-95
Cotton-seed oil	..	..	..	0.922	—	600	—
Linseed oil	..	..	..	0.930	—	above 600	—
Resin oil	..	..	..	0.990	—	600	—
Paraffin oil	..	..	..	0.805	—	340	—
Shale oil	..	..	..	0.870	—	550	—
Creosote (true creosote the pro- duct of the destructive dis- tillation of wood)				1.076	—	410-425	—

APPENDIX E

TIMBER-PRESERVING SPECIFICATIONS.

Year	Name	Substance employed	Specification
1832	J. H. Kyan, Patent No.6253	Deuto-chloride of mercury, or cor- rosive sublimate	1 lb. of salt to 5 gallons of water, used hot or cold. Immersion for from seven to twenty-one days.
1836	" " 7001		
1837	J. J. L. Margary Patent No.7511	Sulphate or ace- tate of copper	1 lb. of salt to 4 gallons of water. Immersion two days per inch of thick- ness of wood.
1838	Sir W. Burnett, Patent No.7747	Chloride of zinc ..	1 lb. of salt to 5 gallons. Immersion for from ten to twenty-one days.
1838	J. Bethell, Patent No.7731	Saline solutions and resinous or bituminous sub- stances. Coal tar thinned with one-third to one- half its own quantity of dead oil. Caoutchouc or resin may be added.	
1865	Dr. Letheby ..	Creosote oil ..	Sp. gr. at 60° F. 1.045- 1.055, as near 1.050 as possible. Not to de- posit naphthalene or para-naphthalene at 40° F. To yield not less than 5 per cent. tar acids, and not less than 90 per cent. of liquid oil at 600° F.
1869 to 1884	Belgian Government	Coal-tar Creosote..	Not to contain more than 30 per cent. naph- thalene at ordinary temperature. Two- thirds must distil above 482° F. None to distil under 392° F.
1883	Dr. Tidy ..	Coal-tar Creosote	To be completely liquid at a temperature of 100°F. Must contain at least 25 per cent. of constitu- ents that do not distil at

Year	Name	Substance employed	Specification
1884	Sir Frederick Abel	Creosoting liquor or heavy oil of tar	a temperature of 600°F. To yield a total of 8 per cent. of tar acids. Completely fluid at 100° F. To contain not less than 20, nor more than 30 per cent. of constituents that do not distil at a temperature of 600° F. To yield not less than 9 per cent. of tar acids. Spec. gravity 1.035 to 1.065.
1864 to 1884	Western Railways of France	Creosote ..	To contain 5 per cent. of tar acids (acide phénique)

EXTRACTS FROM BRITISH STANDARD SPECIFICATION
No. 144-1921.

OF THE BRITISH ENGINEERING STANDARDS ASSOCIATION.¹

1. The Creosote shall be essentially a distillate of Coal Tar and shall be free from any admixture of petroleum and similar oils.
2. The specific gravity shall not be less than 1.015 and not more than 1.07 at 38° C. (100° F.) when compared with water at the same temperature.
3. The material shall become completely liquid when slowly warmed to 38° C. (100° F.) with stirring and on cooling down shall remain completely liquid after standing for 2 hours at 32° C. (90° F.). If the creosote is required for brush application, the latter temperature should be 15° C. (59° F.)
4. The amount of water in the Creosote shall not exceed 3 per cent.
5. When 100 cc. measured at 38° C. (100° F.) of the dry Creosote are distilled from a 250 cc. distillation flask at such a rate that the distillation is complete in about 20 minutes, there shall distil at 760 mm. pressure

up to 205° C. (401° F.)	not more than	7 cc.
„ 230° C. (446° F.)	„ „	40 „
„ 315° C. (599° F.)	„ „	78 „

 the volumes of all fractions being measured at 38° C. (100° F.). The residue above 315° C. (559° F.) shall be soft and not sticky, and its weight shall not be less than 22 gms.
6. The amount of tar acids shall not be less than 5 per cent. and not more than 16 per cent. by volume.
7. The amount of matter insoluble in benzol (benzene) shall not exceed 0.4 per cent. by weight.

The methods of determination of the foregoing are described in the Specification.

¹ Extracted by permission of the British Engineering Standards Association from B.S. Specification No. 144-1921, "Creosote for the Preservation of Timber," official copies of which may be obtained from the offices of the Association, 28, Victoria Street, Westminster, S.W.1, price 2s. 2d. post free.

APPENDIX F

REFERENCES TO AUTHORITIES ALLUDED TO IN THE PRECEDING PAPERS

	No. of Reference
<i>Acridine</i> .—An antiseptic contained in coal-tar oils. "Berichte der deutschen Chemischen Gesellschaft," 1870, p. 746. Also 1883, p. 1971. "Watts' Dic- tionary of Chemistry," second supplement, vol. vii., p. 24. G Lunge, "Distillation of Coal-Tar," p. 73. Acridine detected in old creosoted timber. Author's experiments	1
It is contained in the green oils	2
<i>Bacteria</i> .—By Dr. Antoine Magnin and Dr. George M. Sternberg. New York, 1884	2a
<i>Bethell, John</i> .—Patent for preserving timber, No. 7,731, July, 1838	3
Recommends creosotes containing naphthalene. Min- utes of Proceedings Inst. C.E., vol. xii., p. 228 ..	4
Does not consider creosoting as altogether a chemical process; but desires to fill the pores of the wood with a bituminous asphaltic substance. Minutes of Pro- ceedings Inst. C.E., vol. xxiv., p. 31	5
<i>Burt, H. P.</i> .—"On the Nature and Properties of Timber," Minutes of Proceedings Inst. C.E., vol. xii., p. 206, 1853	6
Describes creosote as becoming a hard, compact mass, at a temperature below 35° Fahrenheit. Minutes of Proceedings Inst. C.E., vol. xii., p. 219	7
Describes creosote as solidifying below 40° Fahrenheit. Minutes of Proceedings Inst. C.E., vol. xxii., p. 255 ..	8
<i>Burnett, Sir William</i> .—Patent for preserving timber, No. 7,747, July, 1838. <i>Idem</i> , No. 8,437, March, 1839 ..	9
<i>Boulton, S. B.</i> .— Patent for preserving timber, No. 734, March, 1865	10
" " " 1,954, May, 1879	11
" " " 625, Jan., 1882	12
" " " 5,723, Dec., 1883	12
Experience in preserving timber against the attacks of the <i>Teredo navalis</i> . Minutes of Proceedings Inst. C.E., vol. xxvii., pp. 564, 565, 566	13

	No. of Ref.
An improvement in creosoting timber, see Pamphlet. Note, No. 26	14
<i>Boucherie, Dr.</i> —Ingenious process for injecting timber. Maxime Paulet. "Traité de la Conservation des Bois," pp. 216 to 224	15
English patent, No. 1,369, 15 June, 1855	
<i>Cato Censorius</i> .—"De Re Rustica," xviii. Use of amurca	16
<i>Coisne, Charles</i> .—Experiments upon separated portions of the creosote oils, as to their comparative efficiency in preserving wood from decay. <i>Annales des Travaux</i> <i>Publics de Belgique</i> , vol. xxii., p. 193; vol. xxiv. p. 147; vol. xxx., p. 49	17
Experiments upon the substance found in creosoted sleepers 18 to 20 years old. <i>Annales des Travaux</i> <i>Publics de Belgique</i> , vol. xxvii., p. 13	18
Also "Collection of Pamphlets relating to Timber Pre- serving." Note No. 22	19
<i>Collection of Pamphlets relating to Timber Preserving</i> . Pre- sented to the Library of the Institution of Civil En- gineers by S. B. Boulton. Bound in one volume. Collection as follows :	
<i>Burt, H. P.</i> —"On the Nature and Properties of Timber." 1853 (previously cited)	20
<i>Bryce, McMaster</i> .—"On the Woods used for Sleepers on the Madras Railway," Minutes of Proceedings Inst. C.E., vol. xxii. p. 241. 1863	21
<i>Coisne, C.</i> —"Note sur l'Application des Huiles Créo- sotées à la Préparation des Bois." 1864	22
<i>Coisne, C.</i> —"Note sur la Conservation des Bois, au Moyen d'Echantillons d'Huiles Créosotées obtenus à différentes Températures." 1866	
<i>Coisne, C.</i> —"Note sur les Bois préparés exposés à Paris en 1867, et Considérations sur les Bois Injectés en Belgique." 1868	
<i>Coisne, C.</i> —"Notes sur les Essences de Bois à employer comme Traverses de Chemins de Fer, leur Préparation, et le Choix à faire des Huiles Créosotées." 1871	
<i>Forestier, Auguste</i> .—"Mémoire sur la Conservation des Bois à la Mer, contre les Ravages du Taret (<i>Teredo</i> <i>navalis</i>)." 1867	23
<i>Clark, Edwin</i> .—"On the Durability of Materials." Dis- cussion at the Institution of Civil Engineers as to the efficacy of creosoting against the attacks of the <i>Teredo navalis</i> . Minutes of Proceedings Inst. C.E., vol. xxvii., p. 554. 1868	24
<i>Boulton, S. B.</i> —"Account of the Products derived from Coal-Tar." Extract from the Reports of the Philo- sophical Society of Glasgow. 1880	25

	No. of Ref.
<i>Boulton, S. B.</i> —"An Improvement in the Process for Creosoting Timber." 1882	26
<i>Williams, Greville.</i> —"The Past, Present, and Future of Coal-Tar." 1880	27
<i>Williams, Greville.</i> —"On the Antiseptic Alkaloids combined in Creosote Oils." 1883. Originally published in the Journal of Gas Lighting for 5th June, 1883 ..	28
<i>Burt, Boulton & Haywood.</i> —"Catalogue of Products obtained from the Residual Substances of Gas Manufacture"	29
<i>Tidy, Dr. C Meymott.</i> —"Report on the Description of Creosote best suited for Creosoting Timber." 1883..	30
<i>Cryptidine.</i> —An antiseptic alkaloid discovered in coal tar by Greville Williams. Transactions of the Royal Society of Edinburgh, vol. xxi., part iii., 1856	31
Its presence detected in old creosoted timber. Collection of pamphlets relating to timber preserving. No. 28	32
<i>Daubenton.</i> —"Essay on Mummies," published with Buffon's Natural History	33
<i>De Gemini.</i> —Experiments on the preservation of wood. Comptes Rendus de l'Académie des Sciences (France), 1848. Bulletin de la Société d'Encouragement, Mai, 1848. Maxime Paulet, "Traité de la Conservation des Bois," p. 263	34
<i>Diodorus Siculus.</i> —Embalmmment of the dead by the Egyptians, Book I., p. 91	35
<i>Dutch Government.</i> —Research and experiments as to the best means for preventing the ravages of the <i>Teredo navalis</i> , "Verslag over den Paalworm." 1863, 1864, 1865. Pamphlets in Dutch, with English translations in the Library of the Institution of Civil Engineers. Also Minutes of Proceedings Inst. C.E., vol. xxvii., pp. 564, 565, 566. Also Maxime Paulet, pp. 168, 310. Also Auguste Forestier. Collection of pamphlets relating to timber preserving. Note No. 23 ..	36
<i>Encyclopædia Britannica.</i> Edition 1810. Dr. McBride's Theory, vol. xvii., p. 526	37
Sir John Pringle and Dr. McBride published lists of antiseptics, vol. xvii., p. 529	38
Sir Humphry Davy recommends corrosive sublimate, and Thomas Wade (1815) suggests the salts of copper, iron and zinc. Supplement, vol. iii., p. 683 ..	39
Mr. Lukin's disastrous experiment with vapours of oils and resin. Supplement, vol. iii., pp. 680, 681 ..	
<i>Forestier, Auguste.</i> —Ingénieur en chef des Ponts et Chaussées. "Mémoires sur la Conservation des Bois à la Mer," 1867. Collection of pamphlets relating to timber preserving. Note 23	40

	No. of Ref.
<i>Herodotus</i> .—Extraction of mineral pitch, "Melpomene," 195. Embalment of the dead by the Egyptians, "Euterpe." Chaps. 86, 87, 88	41 42
<i>Kyan, John Howard</i> . Patents for the use of corrosive sublimate, No. 6,253, September, 1832; No. 7,001 March, 1836	43
<i>Letheby, Dr.</i> —Views on the creosoting process. Journal of the Society of Arts, 15th June, 1860. Letter to Burt & Co., dated 5th June, 1863, stating that two samples of dead oils tested, contain "unusually large proportions," 6.47 per cent. and 10.10 per cent. respectively, of "crude creosote and carbolic acid." Views on the creosoting process. The Journal of Gas Lighting, 9th July, 1867.	44 45 46
<i>Liebig, Baron Justus</i> .—"Chemistry of Agriculture and Physiology," London, 1847. Albumen, pp. 60, 61, 62, 141; eremacausis, pp. 287, 303. Eremacausis not caused by germs, chap. x. Decay of wood, p. 294, chaps. vi. and vii., pp. 310, 319, 357, 363. "Letters on Chemistry," London, 1851. Albumen, Letter XXV. See also p. 352. Eremacausis, pp. 180 to 185. Also pp. 207 to 211. Also Letters XVII. and XIX. Also p. 225.	47
<i>Lunge, Dr. George</i> , Professor of Chemistry at Zurich.—"A Treatise on the Distillation of Coal Tar." Translated from the German. London. Van Voorst, 1882	47a
<i>Margary, J. J. Lloyd</i> .—Patent for preserving timber by salts of copper, No. 7,511. December, 1837	48
<i>Moll, Franz</i> .—First patent mentioning "Kreosot." No. 6,983. January, 1836	49
<i>Naphthalene</i> is abundant in the oils derived from New-castle coals	50
Its use for preserving timber recommended by Mr. John Bethell. Note 4	51
Was present in the creosotes used by Mr. H. P. Burt. Its solidifying properties. Notes 7 and 8	52
Is not soluble in cold water; almost insoluble in boiling water. Greville Williams' article, Naphthalene, in Watts' "Dictionary of Chemistry," vol. iv.	53
Its properties when exposed to heat, experimented on by Dr. Meymott Tidy. Report to the Gas Light Company, dated August, 1883. Note 30	54
Its presence detected in old creosoted timber by Mr. Coisne, by Mr. Boulton, and by Mr. Greville Williams. Note 28	55
Its presence in the creosote oils approved by Dr. Lunge (Note 47a)	55a

	No. of Ref.
<i>Pasteur</i> .—Explanation of the germ theory. Maxime Paulet's "Traité de la Conservation des Bois," p. 64.	
Dr. Tyndall's "Floating Matter of the Air," pp. 9, 27, 121, 135	
Experiment upon saw-dust. Comptes rendus de l'Académie des Sciences for 1863, p. 737	56
"Histoire d'un Savant par un 'Ignorant.'" A Bio- graphy of Mr. Pasteur. Paris, Hetzel, 1883 ..	
<i>Paulet, Maxime</i> .—"Traité de la Conservation des Bois." Paris, 1874. Composition of natrum, chap. i., p. 7 ..	57
Corrosive sublimate, chap. ii., p. 38 ; chap. iii., p. 42 ..	58
Salts of copper and iron, chap. iii., p. 42	59
Dr Boucherie recommends salts of copper, zinc and iron, p. 216	60
Payen reports that the salts of copper can be dissolved out of timber by water, p. 145	61
Paulet reports on the solubility of salts of copper con- tained in timber, pp. 112, 142, 149	62
Tar acids volatile and soluble in water, pp. 148, 149, 329, 330, 331. Putrefaction of albumen is retarded by coagulation. Density of wood and its retention of moisture, p. 98	63
<i>Payne, Charles</i> .—Patents for preserving timber. No. 9,025, 1841. No. 11,256, 1846.	64
<i>Pettigrew, Dr. Thomas Joseph</i> .—"History of Egyptian Mummies." London, 1834. Composition of natrum, chap. v., p. 61 ; chap. vi., pp. 83, 84	65
Rouyer's description of mummies, p. 62	66
Mummies must have been exposed to great heat, p. 62 ..	67
Experiment on the heart of a mummy, p. 60	68
Examination of various mummies. Introduction ; also chaps. v. and vi.	69
<i>Pliny the Elder</i> .—Use of amurca and other oils. Book XV., chaps. iii., vii., and viii.	70
Statue of Diana at Ephesus, preserved by oil of nard. Use of cedar-oil against wood-worm and decay. Book XVI., chap. lxxix.	71
Description of forty-eight kinds of oils. Book XV., chap. vii.	72
Description of pitch, tars, and resins. Book II., chaps. cviii., cix., cx. ; Book V., chap. xxv. ; Book XIV., chap. xxv. ; Book XV., chap. vii. ; Book XVI., chaps. xxi., xxii., xxiii. ; Book XXV., chaps. xxii., xxiii., xxvi., li. ; Book XXIV., chap. xxv.	73
Odoriferous woods last the longest. Book XVI., chap. lxxix.	74
Wood submerged in water is preserved from decay. Book XVI., chaps. lxxx., lxxx. i.	75

	No. of Ref.
On the <i>Teredo</i> . Book XI., chap. i.; Book XVI., chap. lxxx.	76
<i>Rouyer</i> .—Description de l'Égypte, p. 212. See also Pettigrew. Note 66	77
<i>Rottier, D.</i> —Experiments upon the preserving properties of various kinds of creosote oils. Bulletin de l'Académie Royal de Belgique, 1863, vol. xv., p. 424. Also Maxime Paulet's "Traité de la Conservation des Bois," p. 263	78
<i>Seidl, J.</i> —Report on experiments in injecting timber with creosote vapours. "Mittheilungen des Architecten- und Ingenieur-Vereines im Königreiche Böhmen," 1880, p. 25	79
<i>Tar Acids, their Solubility in Water and their Volatility.</i> —Consult the following authorities:	
Boillat, F. Experiment on the instability of carbolic acid (phenol) in connection with albumen after washing with water. "Journal für praktische Chemie," vol. xxv., part 2, pp. 300, 301. Also "Journal of the Chemical Society," vol. xlii.	80
Declat, Dr. "Traité de l'Acide Phénique," Paris, 1841, p. 3	81
Koch, Dr. Robert. "Ueber Desinfection." Pamphlet reprinted from the "Mittheilungen des Kaiserlichen Gesundheits-Amtes." Berlin, 1881	81a
Lemaire, Dr. Jules. "De l'Acide Phénique," Paris, 1865, pp. 37, 38, 40, 45, 47	82
Lister, Professor (now Sir Joseph), in describing the great value of carbolic acid for surgical purposes, speaks of its volatility as an evil as well as a good. Sansom, pp. 224, 256	83
Lunge. "Treatise on the Distillation of Coal-Tar," London, 1882, pp. 204, 205	84
Paulet, Maxime, "Traité de la Conservation des Bois," pp. 148, 149, 329, 330, 331	85
Ott, Dr. Adolph. Journal of the Franklin Institute of Pennsylvania. Sept., 1869	86
Parkes, Dr. E. A. "A Manual of Practical Hygiene," London, 1878, p. 138	87
Pettenkofer. Allgemeine Zeitung, Feb. 4, 1866. "Carbolic acid preserves inert the ferment cells, but when it is removed they become active." <i>Infra</i> , Angus Smith, p. 62	88
Rottier. <i>Supra</i>	89
Sansom, Dr. Arthur Ernest. "The Antiseptic System in Medicine and Surgery." London. Carbolic acid, although requiring a very high temperature for ebullition, is volatile at ordinary temperatures, p. 14. Easily forms compounds which are usually unstable,	

	No. of Ref.
pp. 15, 16. Its powers of coagulation have been over-estimated, p. 28. Its action not chemical, p. 29. When completely volatilized its action ceases, p. 96. Acts solely by killing organized bodies, p. 97. Its solubility in water, pp. 6, 7, 10. Injected into bodies it requires to be renewed after some weeks, p. 124. It is less permanent in its action than coal-tar, p. 123. Carbolic acid is the aerial disinfectant <i>par excellence</i> , p. 208	90
The antiseptic powers of carbolic acid are weakened in the presence of oils, pp. 17, 21, 23, 121, 123, 252 ..	90a
Smith, Angus. "Disinfectants." Edinburgh, 1869, pp. 62, 64, 70, 87. Coagulation of albumen retards, but does not prevent, putrescence, p. 16	91
Tidy, Dr. C. Meymott. Creosote specification and Report to the Gas Light Company, August, 1883, Note 30	92
Williams, Greville. Pamphlet. Note 28	93
Wurtz, Ad. "Dictionnaire de Chimie," vol. ii., p. 797 ..	94
Wolffhugel, G. and G. von Knorre. Article in the <i>Chemisches Centralblatt</i> , 1882, p. 367. Abstract, <i>Journal of the Chemical Society</i> , vol. xlii., p. 367 ..	94a
<i>Tidy, Dr. C. Meymott.</i> —"Handbook of Modern Chemistry." London, 1878. Describes the distinction between "creosote," or "Kreosote," and carbolic acid, p. 571..	95
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Experiments on the creosote oils, and reports to the Gas Light Company. Confirms the results of Mr. Greville Williams' experiments. Note 30	97
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APPENDIX G

Experiment with two specimens of tar oils containing respectively 10 per cent. and 17.5 per cent of tar acids by the ordinary caustic soda test. The object was to ascertain what proportion of the tar acids could be removed by repeated washing with cold water.

SPECIMEN OF MIXED LONDON AND COUNTRY OIL

Test before Experiment.

	Per Cent.
Total distillate at 600° Fahr.	70
Tar acids	10
Water	2
Sp. gr. at 60° Fahrenheit ..	1.068
20 ozs. of oil washed with cold water seventeen times (1,020 ozs. of water used).	

Test after Experiment

Total distillate at 600° Fahr.	70.0
Tar acids	3.5
Water	1.0
Sp. gr. at 60° Fahrenheit	1.071
Again washed with cold water fifteen times (900 ozs. of water used).	

Test after Experiment

Total distillate at 600° Fahr.	69.0
Tar acids	1.5
Water	Free
Sp. gr. at 60° Fahrenheit ..	1.073

SPECIMEN OF COUNTRY OIL

Test before Experiment

	Per Cent.
Total distillate at 600° Fahr.	85.0
Tar acids	17.5
Water	3.0
Sp. gr. at 60° Fahrenheit	1.046
20 ozs. of oil washed with cold water seventeen times (1,020 ozs. of water used).	

Test after Experiment

Total distillate at 600° Fahr.	83
Tar acids	6
Water	3
Sp. gr. at 60° Fahrenheit	1.049
Again washed with cold water fifteen times (900 ozs. of water used).	

Test after Experiment

Total distillate at 600° Fahr.	79.0
Tar acids	3.5
Water	Free
Sp. gr. at 60° Fahrenheit	1.053

It will be seen that by merely washing in cold water the original bulk of tar acids was reduced in the one case from 10 per cent. to 1.5 per cent., in the other case from 17.5 per cent. to 3.5 per cent. The small proportion of tar acid remaining, in both cases, contained no carbolic acid by the bromine and ammonia test; it did not boil until 420° Fahrenheit, which may be considered as too high a temperature even for cresylic acid. It is probably one of the higher phenols.

APPENDIX H

SPECIMENS EXHIBITED DURING THE DISCUSSION UPON MR. S. B. BOULTON'S PAPER ON "THE ANTISEPTIC TREATMENT OF TIMBER"

A piece of oak timber (sound) from the ruins of the Carolus Bridge, Mainz ; erected by Charlemagne, and destroyed by fire.

Portion of an oak pile (sound) which formed part of the first bridge on the Medway at Rochester, driven in about the year 1180. This bridge was destroyed by Simon de Montford.

Portion of an elm pile (sound) which formed part of the second bridge on the Medway at Rochester, driven in about the year 1280, and taken up in the year 1870.

The above three specimens were exhibited to illustrate the fact that timber, deeply immersed and covered with water, will endure unprepared during many ages.

Specimen of fir timber, forming part of a tank disintegrated by a solution of sodium sulphate. The encrusting matter between the concentric rings had been entirely dissolved and removed, so that the rings disintegrate and separate from each other in flakes.

Specimen of wood destroyed by drippings of sulphuric acid. This timber had the appearance of having been carbonized as if by fire.

These two specimens exhibited to show the destructive influence upon wood of various chemical agents.

Two specimens of timber injected, first with natrium and afterwards with creosote oil.

Three specimens of timber injected, first with a solution of copper sulphate and subsequently with creosote oil.

These five foregoing specimens were exhibited to illustrate a theory as regards the preservation of mummies, and also to illustrate the fact that timber can be injected, first with metallic salts and next with oils of tar.

Series of specimens of successful creosoted timber, contributed from various sources, to illustrate the duration of creosoted timber during long periods. All these specimens were perfectly sound.

Portion of a half-round fir sleeper laid in the East Suffolk line in 1858, taken up in 1882.

Portion of a half-round fir sleeper, fifteen years in the ground, from the Mid-Kent line of the South-Eastern Railway Company.

Portion of a rectangular fir sleeper, fifteen years in the ground, from the Great Western Railway Company.

Portion of rectangular fir sleeper, twenty years in the ground (specimen C), contributed by the London & North-Western Railway Company.

Portion of fir sleeper, twenty-eight years in the ground (specimen H), contributed by the London and North-Western Railway Company.

Portion of rectangular fir sleeper, thirty-two years in the ground (specimen M), contributed by the London & North-Western Railway Company.

Portion of rectangular fir sleeper, fifteen years in the ground (specimen O), contributed by the London, Chatham & Dover Railway Company.

Portion of a post belonging to a fence from the Victoria Docks, after twenty-nine years' duration, contributed by Messrs Burt, Boulton & Haywood (specimen G).

Portions of the preceding specimens had been analyzed at the Author's laboratory at Silvertown, as mentioned in the Paper. These also form portions of the specimens analyzed by Mr. Greville Williams.

Specimens of products derived from coal. (See also Plate 3.)

	NAME				FORMULA
Coal-tar	..	..	..	..	—
Gas liquor	..	..	..	..	—
Sulphate of ammonia			..	..	$(\text{NH}_4)_2\text{SO}_4$
Crude naphtha	..	..	..	..	—
Once-run naphtha	..	..	..	..	—
Benzol commercial	..	..	..	..	—
Benzol pure	..	..	..	..	C_6H_6
Nitrobenzol	..	..	..	..	$\text{C}_6\text{H}_5\text{NO}_2$
Aniline	..	..	..	..	$\text{C}_6\text{H}_7\text{N}$
Toluol commercial	..	..	..	..	—
Toluol pure	..	..	..	..	C_7H_8
Nitrotoluol	..	..	..	..	$\text{C}_7\text{H}_7\text{NO}_2$
Toluidine	..	..	..	..	—

NAME				FORMULA
Xylol	..	..	..	C_8H_{10}
Nitroxylol	..	..	..	$C_8H_9NO_2$
Cumol	..	..	..	C_9H_{12}
Best solvent naphtha :		..	..	—
Pyridine	..	..	..	C_5H_5N
Carbolic acid crude	..	..	..	—
Carbolic acid pure	..	..	..	C_6H_6O
Picric acid	..	..	..	$C_6H_3(NO_2)_3OH$
Aurin	..	..	..	$C_{20}H_{14}O_3$
Cresylic acid	..	..	..	C_7H_8O
Creosote	..	..	..	—
Creosote salts	..	..	..	—
Naphthalene in albocarbon form			..	$C_{10}H_8$
Naphthalene pure in sublimed form				$C_{10}H_8$
Naphthalene pure in crystallized form				$C_{10}H_8$
Nitronaphthalene	..	..	..	$C_{10}H_7NO_2$
Naphthylamine	..	..	..	$C_{10}H_7NH_2$
Napthol	..	..	..	$C_{10}H_7OH$
Phthalic anhydride	..	..	..	$C_8H_4O_3$
Quinoline	..	..	..	C_9H_7N
Phenanthrene	..	..	..	$C_{14}H_{10}$
Phenanthrene quinone	..	..	..	$C_{14}H_8O_2$
Carbazol	..	..	..	$C_{12}H_9N$
Anthracene Oil	..	..	..	—
Green oil	..	..	..	—
Anthracene pressed	..	..	..	—
Anthracene pure	..	..	..	$C_{14}H_{10}$
Anthraquinone commercial	..	..	..	—
Anthraquinone crystallized	..	..	..	$C_{14}H_8O_2$
Anthraquinone sublimed	..	..	..	$C_{14}H_8O_2$
Alizarine in paste	..	..	..	—
Purpurine in paste	..	..	..	$C_{14}H_8O_5$
Alizarine sublimed	..	..	..	$C_{14}H_8O_4$
Acridine	..	..	..	$C_{13}H_9N$
Pyrene	..	..	..	$C_{16}H_{10}$
Pyrene quinone	..	..	..	$C_{16}H_8O_2$

	NAME				FORMULA
Chrysene	..	..	..	..	$C_{18}H_{12}$
Chrysoquinone	..	..	..	..	$C_{18}H_{10}O$

Pitch —

Heavy tar acids extracted from green oil

Heavy tar oil extracted from old creosoted woods

Anthracene " " "

Naphthalene " " "

Scotch creosote

Specimens of substances not derived from coal-tar, to illustrate
Table 2.

Bone oil	Resin oil
Olive oil	Paraffin oil
Palm oil	Shale oil
Cotton-seed oil	Cresote from wood
Linseed oil	

APPENDIX I

August, 1883.

REPORT OF DR. C. MEYMÖTT TIDY, M.B., F.C.S. ON THE DESCRIPTION OF CREOSOTE BEST SUITED FOR CREOSOTING TIMBER

To the Directors of the Gas Light and Coke Company

Gentlemen,—In accordance with instructions I received from you to consider and report on the character of creosote best suited for creosoting timber, I have, during the past fifteen months, devoted a considerable amount of attention to this question, and made numerous experiments thereupon. I now beg to report the results of my investigations.

Let me define, first of all, exactly what I understand by the word “creosote.” This is important, seeing that it does not imply a compound of fixed chemical composition. It is, in fact, a composite liquid, made up of a variety of chemical bodies in different proportions, the quality depending (first) on the kind of coal from which the coal-tar is obtained, and (secondly) on the details of the distillation and treatment.

Broadly speaking, I mean by the word creosote a product of the distillation of coal-tar after it has reached a temperature of about 300° Fahrenheit, in other words, after what is known as the light oil has distilled over.

It may be taken that about one-third the bulk of the tar consists of the “creosote” or “heavy oil” employed in creosoting timber.

The process of creosoting is effected by placing well-weathered wood in a vessel so constructed that a more or less perfect vacuum may be obtained. The creosote, heated to a temperature of from 100° to 120° Fahrenheit, is allowed to pass into the exhausted reservoir, and thus finds its way into the pores of the wood.

The advantages to be derived from the process are, I consider, of a *threefold* nature, and I give them in what appears to me to be the order of their importance :—

1st. *A physical action.* A very greatly increased solidity is effected by choking up the pores, thus agglutinating the whole mass of the wood into a more or less solid block. Apart from its rendering the wood more solid, this physical action is important in preventing the subsequent absorption of moisture.

2nd. *A physiological action.* The smell of the creosote imparted to the wood prevents germinal life, well known to be destructive to timber, from being developed within it. Seeing that the preservation of timber has been effected by such materials as chloride of zinc, sulphate of copper, etc., with greater or less success, and that the action of these bodies must be mainly, although I admit not entirely, dependent on their toxic properties, this physiological action is one of importance. It must be remembered, moreover, that creosote has the advantage of a well-marked smell, which odour most of the lower animals dislike. In this respect it is superior to the other bodies I have named.

Further, it is worth pointing out that all the constituents of the coal-tar, and not the tar acids only, have a more or less well-marked tarry odour.

3rd. *A chemical action.* Respecting the chemical action, I would draw attention to the fact that tar acids are not only antiseptic, but that they possess the power of coagulating albumen. It is to this latter action that I shall have to refer later on in this report, as playing an important part, in my opinion, in the preservation of the timber.

Having now dealt with what I conceive to be the details involved in the process of creosoting, the two following questions arise : (1st) Upon what constituents of the creosote does its value specially depend, and what are the relative values of its different constituents? (2nd) If there be constituents in the creosote, which of themselves possess no special value, do they in any respect lessen the activity of the valuable constituents?

The importance of considering the precise value of the several constituents of creosote, arises as follows :

Speaking generally, creosote may be divided into two classes, London and country creosotes. By London creosote we mean the creosote derived from the tars of the London gas-works, the east coast generally, and from the gas-works of towns such as Southampton, Brighton, etc., where the coal employed is Newcastle coal. So far as I am able to learn, the larger proportion of the creosote produced in England is of this character. The two creosotes, however, being very different in their composition, it becomes important to consider them separately.

The London creosote has a somewhat high specific gravity, and contains a comparatively large percentage of naphthalene, and a small percentage (i.e. less than 10 per cent.) of tar acids. Further, it contains a considerable quantity of the heavier portions of the oil, that is, of those portions not volatile at a temperature below 600° Fahrenheit.

The Country creosote, on the other hand, has a less specific gravity, and is considerably more fluid than London creosote. It contains considerably less naphthalene than the London creosote, a larger total percentage of tar acids, and a smaller percentage of the heavier portions of the oil present.

The real question I have had in view in this inquiry being country creosotes *v.* London creosotes, it became necessary to inquire the relative values of the heavier portions of the oil, of the naphthalene, and of the tar acids in creosoting. In view of making what I have to say clear, I may venture to place before you what I conceive to take place in the operation of creosoting.

The creosote, having been sufficiently heated to bring the whole of the suspended constituents into a perfectly liquid condition, is driven into the wood, from which the air has been more or less completely exhausted. The tar acids, in the first instance, effect the coagulation of the albumen of the wood sap. This coagulated albumen mixes with the naphthalene of the creosote, which so soon as the temperature becomes sufficiently reduced is re-deposited, and forms, along with the heavier portions of the oil, a solid magma within the pores and fibres of the wood. That this formation of a solid magma actually occurs, I have convinced myself by numerous microscopic examinations of creosoted timbers.

TAR ACIDS

The success of the process, therefore, being presumably assisted by the coagulation of the albumen, the question arises, What quantity of tar acids is necessary to effect this object?

To determine this point I have made a variety of experiments.

There is very little doubt in my mind supposing that 10 lb. of creosote per square foot be injected into the wood, and that the timber be of the kind ordinarily used (although in this respect different kinds of woods do not differ so much as might be supposed), that 2, or from that to 3, per cent. of tar acids would amply suffice to effect this coagulation of the sap albumen.

We are now led to consider if any value, and if any, what value, is to be ascribed to the tar acids beyond that needed to effect the coagulation of the albumen.

I am far from prepared to say they are otherwise entirely valueless. Still, it is a remarkable fact I have over and over again verified, that in the timbers that have been creosoted for a considerable time (say a year) very small quantities indeed (if any) of free tar acids are to be found.

I have upon this point instituted a series of examinations of sleepers obtained from independent sources, and of ages varying from one to twenty years, and it is a fact worth noting that within a very short time after a sleeper has been in use the tar acids appear to be entirely dissipated.¹

Seeing, however, that the life of a sleeper is by no means so

¹This report was written some time before the appearance of Mr. Greville Williams' Paper. My own results, I may say, are in entire accord with his.

limited, the facts I have mentioned suffice to show that the action of the tar acids *per se* cannot have any very great or permanently preservative influence in creosoting.

I admit it was natural to suppose that bodies, commonly regarded as powerfully antiseptic, should have been the active agents in the process. Further I must admit that it was with such view I commenced this inquiry. My recent investigations, however, have clearly shown that the value of the tar acids in the creosoting process has been greatly over-estimated.

I am convinced that so long as the quantity of carbolic acid present in the creosote is sufficient to coagulate the albumen of the wood sap, that that, for practical purposes, is sufficient.

NAPHTHALENE

I have now to consider the value of the naphthalene.

I am disposed to think that this body is of infinitely greater value than at first sight appears. Admitting that, as an antiseptic, it is inferior to the tar acids, nevertheless, so far as preservative action alone is concerned, it must not be supposed to be inoperative. Its special value, however, consists in helping to render the wood solid.

But it may be said, granting this to be the case, naphthalene is so volatile that the heat of the sun, especially the intense heat of an Indian climate, would soon drive the whole of it off. It is true that on exposing a block of creosoted timber in an oven to a temperature of 54.5° Centigrade (130° Fahrenheit), and this may be taken to be an extreme tropical heat, the door of the oven, after a short time, shows conclusively that some of the naphthalene in the sleeper has undergone volatilization by the heat applied.

I would, however, direct attention to the following experiment :

I exposed a large block of creosoted timber (accurately weighed) to a temperature of 65.5° Centigrade (150° Fahrenheit). On weighing this at the end of twenty-four hours, I found it to have lost 1,200 grains. On exposing the same block to the same temperature for another twenty-four hours, it lost 135 grains, whilst on continuing the exposure for a third twenty-four hours, it only lost 15 grains. After this the loss was practically nil.

I now planed off about $\frac{1}{4}$ inch of the block I had already heated. This done, I again exposed it to a heat of 54.5° Centigrade (130° Fahrenheit) for twenty-four hours, during which time it lost 1,150 grains. The loss on the second day was less than 100 grains, whilst on succeeding days the loss was practically nil.

The surface of the wood was again planed off, and similar experiments repeated a third time, with almost identical results.

From numerous microscopical examinations of the timber, and from the experiments I have described, I consider that I am justified in drawing the following conclusions *re naphthalene* :

1st. That supposing, for the sake of argument, naphthalene possesses no great antiseptic power, nevertheless it acts beneficially by clogging up the pores of the wood, forming a more or less solid magma with the coagulated albumen. In this way it assists the physical part of the creosoting process, upon which the preservation of the timber materially depends.

2nd. That although a certain quantity of naphthalene would undoubtedly be volatilized by a tropical heat, nevertheless that the loss would practically be limited to the *surface* of the timber, and would be complete a day or two after exposure, the naphthalene in the deeper parts of the wood remaining fixed by incorporation with the albumen coagulated by the action of the tar acids.

3rd. That inasmuch as the naphthalene cannot injure the action of the tar acids, or other constituents of the creosote, and is itself a positive benefit to the process, there is not only no object in requiring that the oil used for creosoting should be free from naphthalene, but that it would be inadvisable to demand such freedom.

There are many other facts that in my judgment corroborate the views I have expressed. Thus I am given to understand that during the twelve years after the process of creosoting was first introduced into India, the whole of the sleepers were prepared with heavy London creosote (that is, a creosote highly charged with naphthalene), with the occasional admixture of a small quantity of country oil for the purpose of dilution.

It is perfectly certain, further, that it was on account of the good results so obtained that creosoting became a process of acknowledged utility.

So far as I can learn, it was not until the country oils became more extensively used that any complaints respecting the inefficiency of the process arose. From independent inquiries, I think there is the strongest possible reason to believe that the sleepers that proved unsatisfactory had been prepared with country, and not with London oil.

HEAVY OILS

Nothing has impressed me more strongly in the course of these inquiries than the value of the heavy oils present in the creosote, that is, of the oils that do not distil over under 600° Fahrenheit. Of a certain antiseptic power, and very difficult of volatilization, they are, I believe, bodies of great value in the oil employed in the creosoting process.

I have carefully examined numerous samples of the creosote supplied by your Company, and I give herewith the analysis of eighteen samples :

(Here follows an analysis of eighteen samples, alluded to in Mr. Boulton's reply.)

After a very careful consideration of the conditions necessary

to ensure the successful creosoting of timber, it appears to me that the following points need special attention :

1. That the timber should be well dried, so that the pores of the wood may be completely pervious.

2. That the creosote should be of a heavy, rather than of a light description, i.e. that it should contain oils which are given off at high temperatures, together with other matters that become solid within the timber after the creosote has been allowed to cool to a normal temperature.

3. That as much creosote should be put into the timber as the timber can possibly be made to absorb.

Taking into consideration the whole body of the evidence now before me, and which I have submitted to you in this report in part only, I am of opinion that no oil could be better suited than your own for the purpose of creosoting timber, and I would suggest the following as a specification for creosote that would, in my judgment, ensure to engineers and others interested in the process the best possible results :

1. That the creosote should be completely liquid at a temperature of 100° Fahrenheit, no deposit afterwards taking place until the oil registers a temperature of 93° Fahrenheit.

2. That the creosote shall contain at least 25 per cent. of constituents that do not distil over at a temperature of 600° Fahrenheit.

3. That, tested by the process hereafter to be described, the creosote shall yield a total of 8 per cent. of tar acids.

There are certain details connected with this specification to which I desire to draw attention.

1. The omission of any clause specifying the specific gravity of the creosote to be used. I have done this advisedly, because of the extreme difficulty in taking the gravity of creosote at normal temperatures with the 1,000-grain bottle, and the practical uselessness in my judgment of employing a hydrometer for the purpose. If it be considered necessary to introduce a specific gravity clause, I would suggest that the gravity be between 1.040 and 1.065, water being 1.000. I am of opinion, however, that for practical purposes a specific gravity clause is altogether unnecessary.

2. Believing strongly as I do in the value of those constituents of the oil that are the most difficult to volatilize, I have deemed it right to suggest a clause to the effect that the creosote shall contain at least 25 per cent. of matters that distil over above 600° Fahrenheit.

3. I have made a large number of experiments as to the best method by which the estimation of the tar acids may be determined.

I note :

- (a) That very slight differences in the strength of the solutions used, and in methods of manipulation, considerably influence

the results obtained. I therefore deem it necessary that, as a part of the specification, the process to be employed for estimating the acids should be exactly stated.

(b) I have failed to discover any easy method of separating the carbolic from the other tar acids. I have tried for this purpose numerous experiments, but with such unsatisfactory results that I have decided to recommend that the total quantity of tar acids only should be stated. Further, the fact that as preservatives one kind of tar acid is, so far as we know, as good as any other renders a further separation of the acids in my judgment unnecessary. My analyses of samples will show that in fixing not less than 8 per cent. of total tar acids, we obtain a fair index of the purity and genuineness of the creosote.

I shall be happy, if the Board wish it, to enter into further details upon such points as they may deem desirable.—I have the honour, gentlemen, to remain, your obedient servant,

(Signed) C. MEYMOTT TIDY, M.B., F.C.S.

Professor of Chemistry and of Forensic Medicine
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Dr. Tidy's Specification for Creosote

1. That the creosote shall be completely liquid at a temperature of 100° Fahrenheit, no deposit afterwards taking place until the oil registers a temperature of 93° Fahrenheit.

2. That the creosote shall contain at least 25 per cent. of constituents that do not distill over a temperature of 600° Fahrenheit.

3. That, tested by the process hereafter to be described, the creosote shall yield a total of 8 per cent. of tar acids.

Process to be Adopted for Determining the Coal Tar Acids

1. 100 c.c. of the well-mixed creosote is to be distilled at a temperature of 600° Fahrenheit until no further distillate comes over. The distillate so obtained is to be mixed and well shaken in a stoppered flask with 30 c.c. of the solution of caustic soda, having a specific gravity of 1,200, water being 1,000. The mixture is then to be heated. This done, the stopper is to be replaced in the flask, and the hot mixture again shaken vigorously for at least a minute.

The contents of the flask are now to be poured into a separating funnel and the soda solution drawn off. The creosote is to be heated a second and a third time in a similar manner with the

caustic soda solution, except that only 20 c.c. of the soda solution shall be used for the second and third extractions, instead of 30 c.c. as in the first extraction.

2. The three soda solutions are now to be mixed together. *When cold* any particles of creosote are to be got rid of by means of a separating funnel. This done, the solution is to be thoroughly boiled in order to expel the last traces of creosote present in the solution. The mixture is then to be allowed to cool. When cold, dilute sulphuric acid (1 of acid to 3 of water) is to be added (about 35 c.c. will be required) until the solution becomes slightly acid to litmus. The whole is then to be poured into a separating funnel, and allowed to stand until perfectly cold, and the tar acids well separated.

3. The tar acids are now to be dissolved in 20 c.c. of the caustic soda solution (specific gravity 1.200), and 10 c.c. of water. The mixture is then to be boiled and filtered through a funnel fitted with a plug of asbestos. The asbestos plug is to be washed with not more than 5 c.c. of boiling water. The solution is to be allowed to cool *perfectly* in a 100 c.c. measure. It is then to be rendered slightly acid with dilute sulphuric acid (1 to 3), (10 c.c. will probably be found sufficient for this purpose). The whole is again allowed to stand *for two hours* until *perfectly cold*, when the percentage of the tar acids is to be read off.

Process to be Adopted in Estimating the Quantity of Distillate

The operation is to be conducted in a retort (fitted with a thermometer) immersed in an oil or hot-air bath. The heat at first is to be low, and the temperature gradually raised to 600° Fahrenheit, and continued until no further matters distil over.

APPENDIX J

CORRESPONDENCE

BETWEEN MR. BOULTON AND THE GAS LIGHT AND COKE CO.

Attention has been directed to the fact that there is appended to Dr. Tidy's report to the Gas Light and Coke Co. an analysis of eighteen specimens of creosote oils manufactured by that company, and that these creosotes do not represent the type of creosote recommended by Dr. Tidy himself.

It has been assumed that this list represents the average type of London creosotes. This, however, is not the case, as the typical London creosotes do not contain so large a quantity of tar acids, and are of a heavier specific gravity, and distil at a higher boiling-point than the eighteen specimens in question.

The following correspondence will explain the matter :

Copy of letter to the Gas Light and Coke Co.

" 64, Cannon Street, London, E.C., May 22nd, 1884.

" J. ORWELL PHILLIPS, Esq., Secretary,

" Gas Light and Coke Co., Horseferry Road.

" Dear Sir,—In my Paper on the 'Antiseptic Treatment of Timber,' recently read at the Institution of Civil Engineers, and with reference to the heavy oils derived from the tars of the London district, I stated that those oils did not, as a rule, contain more than from 4 to 7 per cent. of tar acids as they came from the still. This fact I derived from a very considerable experience in distilling the tars of various companies, including those of your Company previous to the erection of tar-distilling apparatus at your Beckton works.

" On mentioning this to your representative, Mr. Blagden, yesterday, he stated that on your present manufacture your average of tar acids was 6 per cent., which agrees with my previous experience.

" If your Board confirms this, I shall be much obliged if they will authorize me to send it in as statistical information to be included in the Appendix to my Paper. This does not, of course, interfere with the fact that these creosotes can have their proportion of tar acids raised by removing some of the heavier portions of the oils, as was the case with the samples

tabulated in Dr. Tidy's printed report to your Company, dated August, 1883.—I remain, dear sir,

“Yours very truly,

“ (Signed) S. B. BOULTON.”

Copy of letter received from the Gas Light and Coke Co. in reply to the above :

“ The Gas Light and Coke Co.,

“ Horseferry Road, Westminster, May 23rd, 1884.

“ Dear Sir,—The Directors have not the least objection to the statement contained in your letter of the 22nd inst., and you are perfectly at liberty to express their concurrence in it.—Faithfully yours,

“ (Signed) J. O. PHILLIPS, Secretary.

“ S. B. BOULTON, Esq., 64, Cannon Street, E.C.”

APPENDIX K

ON DISINFECTION

BY DR. ROBERT KOCH

Mittheilungen des kaiserlichen Gesundheits-Amtes. Berlin, 1881.

Condensed translation by D. BENDIX

In consequence of the defective knowledge of infectious substances, and the circumstance that these substances have not yet been classified and organized, it was not possible to investigate with satisfaction the activity of the various disinfecting agents which have been proposed from time to time. According to the present standing of science, it would be necessary to subject a disinfectant successively to all the infectious substances against which it is proposed to use it.

To test the action of disinfectants on micro-organisms only would not be correct, as a number of the infectious substances have not yet been recognized as micro-organisms, and it is therefore necessary to include also the non-organized ferments in investigating this action. It would, furthermore, be unreasonable to choose only such disinfectants as will satisfy all the conditions under which it is proposed to disinfect the substance.

In order to ensure disinfection, it is requisite to use the disinfecting agent within the range of its safe sphere of activity, and not to subject it to requirements which, from a chemical and physical point, it cannot fulfil. It therefore becomes necessary, in testing a disinfectant, to take into consideration the conditions under which it is proposed to use the same in practice. The question at what stage can the action of a disinfectant be regarded as sufficient can be answered only in one way, viz. the action is considered complete when all vitality and the germs from which new life is again developed have been completely destroyed; for instance, disinfecting agents which are not capable of completely destroying fungi cannot be used for the disinfection of objects which are infected by skin diseases. In a similar manner, a disinfectant which allows bacteria and their spores to live cannot be employed for diseases in which bacteria have been proved to cause the disease. Such diseases, in consequence of their number and importance, occupy the first place among the infectious diseases; it therefore becomes necessary, in examining a disinfectant, to test its action on

bacteria and their spores. If it proves wholly ineffective, it should be struck out of the number of the ordinary agents used for destroying infectious diseases. In special cases, however, it may be still active. It should further be observed whether the agent affects the ordinary form of bacteria and also the spores, and unless it is active in the latter case also it cannot be regarded as fulfilling all its requirements. In order to test the final action of the disinfectants employed, the Author in his experiments used cultivated bacteria such as are not often found, as contaminating the atmosphere.

In judging of the capability of development the objects of disinfection were tested on a solid nutritive substance (boiled potatoes, nutritive gelatine, etc.). In testing the action of a disinfectant the following points should be taken into consideration; it should be ascertained whether the agent is able to kill all organisms; for this it suffices to prove that the spores of bacilli have been killed, as formations of greater resisting power are not yet known. It is, however, necessary to test the action of the disinfectant in destroying micro-organisms, and also its power of arresting their development in suitable nutritive solutions; finally, it is necessary, in order to obtain a safe result, to take into account the concentration of the disinfectant, the duration of the action, the influence of solvents, temperature, etc.

Referring to the action of carbolic acid in arresting the development of the spores of splenic fever germs, the Author mentions that it is very slight; that even after five days' action of a 2 per cent. solution of carbolic acid the spores show distinct signs of vitality, and a 1 per cent. had no perceptible action on the spores even after fifteen days. As, however, the practical utility of a disinfectant is dependent upon the rapidity with which it acts, and, as in the case of carbolic acid, rapid action takes place only when concentrated solutions are used, the value of carbolic acid is much limited as a germicide. For the destruction of spores it is altogether useless, being almost without action. In cases, however, where it is desired to destroy micro-organisms free from spores it may be used with advantage, and it is in consequence of this circumstance that carbolic acid owes its reputation as a disinfectant. The experiments, which have been conducted with a view to determine the disinfecting value of carbolic acid, showed that 1 gram of pure carbolic acid is able to completely prevent the development of splenic fever bacilli in 850 cubic centimetres of a nutritive solution; moreover, 1 gram of carbolic acid in 1,250 grams of nutritive solution perceptibly prevents their development. These numbers apply only to splenic fever bacilli; other bacteria are influenced by carbolic acid in a less degree.

In determining the activity of carbolic acid in a gaseous form, in which, according to Von Scholte and Gaertner, it is effective when 15 grams are vaporized per cubic metre of the air, it is

questionable whether the small amounts of carbolic acid which are volatilized at the ordinary temperature, if allowed to remain in contact for some time with the objects to be disinfected, would not exhibit the same disinfecting action. The experiments which have been made in this direction have shown that the vapour of carbolic acid which is given off at the ordinary temperature is quite unable to influence the germinating power of the spores of bacilli even after six weeks' action. At an elevated temperature, however, the vapour of carbolic acid proves to be more active. At 55° Centigrade many of the spores were destroyed after half an hour's action; after three hours but little germinating power remained, and after five to six hours the destruction of all germs was completed. Disinfection with the vapour of carbolic acid can, however, be of practical utility only if the action be completed in half an hour. It is not possible, however, to obtain this result even by the application of an elevated temperature. It therefore becomes necessary to abandon the use of carbolic acid vapour for the disinfection of large objects. Other disinfectants behave like carbolic acid at an elevated temperature. The preceding experiments have reference only to aqueous solutions of carbolic acid; the results of the experiments made with other solvents were very remarkable, inasmuch as they showed that solutions in oil or in alcohol do not exhibit the slightest antiseptic action. This remarkable coincidence was noticed also with other substances, such as salicylic acid, thymol, etc. If, however, carbolic oil is brought into contact with watery substances—for instance, the tissues of the human body, wounds, etc.—a portion of the carbolic acid is undoubtedly given up, and in this case it is possible to observe signs of antiseptic action. By taking into consideration the circumstance that a 1 or 2 or even 5 per cent. solution of carbolic acid fails to exercise any perceptible influence on the spores of bacteria during the short period of an operation, and that, in order to arrest the growth of bacteria in a solution, the carbolic acid must be permanently present in the proportion of 1 to 400, it is not surprising to find bacteria in Lister's dressings, in spite of the careful way in which they are prepared.

The experiments which have been made on the disinfecting property of sulphurous acid have also given a remarkable result. It has been found that when sulphurous acid is allowed to act on dry objects, or in the presence of water or steam, it does not possess any real disinfecting value. The action of aqueous solutions of sulphurous acid on the spores of splenic fever germs is comparatively small; if, on the contrary, the objects to be disinfected are moistened before treatment with sulphurous acid, the activity becomes greater. All experiments, including those which have been made under the most favourable conditions, have shown that sulphurous acid is not a destroyer of all germs of organic life. Sulphurous acid must therefore be regarded as a disinfectant whose action is uncertain; the same applies also to

the double sulphite of lime, which is frequently used as a substitute for sulphurous acid.

The third disinfectant included in the Author's investigation was chloride of zinc. It is said that the action of this substance can be depended upon in 1 per cent. solutions. The result of these experiments showed, however, that a 5 per cent. solution of chloride of zinc did not affect the development power of the spores of splenic fever germs which had been placed in the same for one month. It is not even possible to speak of chloride of zinc possessing the property of perceptibly arresting the development of bacteria.

The preceding investigations have shown that three of the substances hitherto mostly employed as disinfectants in no way correspond with the expectations put upon them. The disinfecting value of carbolic acid is far smaller than has been assumed hitherto, whilst sulphurous acid has proved to be unreliable, and chloride of zinc perfectly useless. In consequence of this the disinfecting value of a further series of agents was investigated, the substances employed being those which had already been recommended as disinfectants, or probably possessed disinfecting properties. It was observed in most cases that the oily as well as the alcoholic solution was of no action, whilst the aqueous solution was active to a greater or less degree. It may be added that glycerine, like alcohol, fails to have the slightest action on the spores of splenic fever bacilli. It has already been remarked that the disinfecting agent to be of practical utility should not merely be reliable, but also quick in its action; in practice, the time of action should not exceed more than twenty-four hours, otherwise the operation becomes either troublesome or impracticable. Again, in practice only such agents are of use which destroy all germs of organic life within a period of twenty-four hours. From a long series of substances experimented with, only corrosive sublimate, osmic acid, and permanganate of potash have fulfilled the above requirements, in addition to chlorine, bromine and iodine. Permanganate of potash, however, only acts when the solution contains 5 per cent. A series of experiments was made also in reference to the action of arresting the development of germs. Both series of experiments showed that only a few substances are of practical value as disinfectants. If the difference between these agents which completely destroy the vital energies and those which arrest development, is upheld, chlorine, bromine, and corrosive sublimate belong to the first category, whilst corrosive sublimate, ethereal oils, thymol, and amyl alcohol belong to the second category.

Experiments have been made to test the value of bromine and corrosive sublimate for special cases. For the disinfection of closed rooms, bromine may be employed; it is necessary, however, that the disinfectant remains in contact with the walls for as long a period as possible. On the whole, however, the

disinfection with bromine would be too expensive an operation.

With regard to corrosive sublimate, it is surprising to find that the powerful action which this agent possesses has not been utilized to a larger extent. Corrosive sublimate is the only disinfectant which acts rapidly after the first application, and without any preliminary treatment of the objects to be disinfected. Its strongly poisonous properties only have prevented it from being used on a large scale. It must, however, be borne in mind that it is not necessary to allow the disinfecting agent to remain permanently on the object to be treated, and that it can be removed after a short time by repeated washings with water. The disinfection by means of corrosive sublimate is not, however, suitable for a continuous process, as in the disinfection of liquids precipitates are formed which, on repeated disinfection, accumulate, and in consequence of the presence of large quantities of mercury may give rise to injurious effects.

APPENDIX L

CONTRIBUTIONS TO THE STUDY OF ANTISEPTICS

BY F. BOILLAT

Journal für praktische Chemie, vol. xxv., pp. 300-9

Translation

The researches recorded in this Paper were undertaken on account of the appearance of a pamphlet on disinfection by Dr. R. Koch. Koch states therein that of the substances at present employed as antiseptics, the only ones worthy of the name are chlorine, bromine, iodine, corrosive sublimate, with possibly potassium permanganate and osmic acid. This contradiction of generally accepted facts is not, however, considered as strong as it appears. In medicine, and more especially in surgery, it is sufficient if the antiseptic employed is capable of preventing the formation of micro-organisms, which are detected by examining the wound and its secreted matter under the microscope, and if the propagation of organisms is arrested for a time long enough to allow the wound to heal, the antiseptic has fulfilled all its requirements. It has, however, never been determined why, by the use of a particular antiseptic, putrefaction and the development of micro-organisms is prevented, and it has been supposed in general that the substance destroys germs or arrests their propagation. It is evident, however, that substances such as phenol, chloride of zinc, acids, corrosive sublimate, ethereal oils, etc., all of which differ in chemical constitution, cannot possibly act on the vitality and development of bacteria in the same destructive manner. Moreover, a number of these micro-organisms, e.g., the splenetic-fever germs, form spores which, as may be expected, resist the action of antiseptics very powerfully. As soon as inquiries are made into the injurious effects of antiseptics on the development and vitality of organisms and their spores, it immediately becomes necessary to subject antiseptic agents to a proper classification. Koch, who has investigated the action of various antiseptics on definite species—*Monas prodigiosa* and *Bacillus anthracis*—by allowing the micro-organisms under examination to remain in the antiseptic medium for a longer or shorter period, and subsequently introducing them into a suitable nutritive solution, and regarding the appearance or non-appearance of their development and propagation as a criterion of their vitality, must necessarily

have arrived at a different opinion with regard to the efficacy of many antiseptic substances. On reading through his work, however, one readily conceives that even his mode of judging the value of an antiseptic is one-sided. For instance, the spores of the splenetic fever organism, after being preserved for many days in a 1 per cent. aqueous solution of phenol, or in a 5 per cent. solution of calcium chloride, do not lose their capability of development; their propagation is, however, arrested, and this is of great importance for medical purposes, for, although substances like chlorine, bromine, acids, etc., would effectually destroy bacteria and their spores, they would in most cases, when applied in the same, or even in less concentration, destroy the tissues of animal organisms. The application of such substances for the treatment of wounds is therefore not practicable. Until it is possible to find a specific poison for germs which will not injure the human organism, the antiseptics employed for the treatment of wounds will be those which are more or less injurious to the animal tissues, but severely injure the vitality of micro-organisms, i.e. arrest their development. The use of destructive disinfectants, such as alkaline solutions, acids, etc., is adapted only, and that to a limited extent, to the preservation of lifeless objects. This explains why, e.g., chloride of zinc, although it does not kill the spores of the splenetic fever germs in a 5 per cent. solution, is nevertheless a good antiseptic agent. Koch erroneously asserts that chloride of zinc does not possess the property of arresting the development of bacteria.

Most antiseptics are characterized by the circumstance that they coagulate dissolved albumen, forming permanent insoluble compounds therewith. On treating blood serum or egg albumen with a dilute solution of sulphate or chloride of zinc, Lieberkühn's zinc albuminate having the composition $C_{72} H_{112} N_{18} S O_{22} + Zn O_2 H_2$, and containing 4.74 per cent. zinc, is formed. A similar reaction occurs when the wound is treated with the solution of a metallic salt. That chloride of zinc, corrosive sublimate, chloride of iron, etc., do not remain as such on the surface of the wound, but combine with the albumen of the tissues, there is no longer a doubt. In order to determine how far these metallic salts, when placed on wounds or brought into contact with albumen, act as antiseptics, it is necessary to investigate the behaviour of micro-organisms on such albuminous metallic precipitates. Such experiments have, to my knowledge, never been made, and at the suggestion of Professor Nencki I have undertaken this work in the interest of a rational study of antiseptics.

Samples of blood serum and egg albumen, the latter diluted with three or four times its weight of water, were treated with an excess of solutions of phenol, chloride of zinc, sulphate of copper, and corrosive sublimate, and the resulting precipitates washed on filters until the wash-water was free from the precipitant;

2 or 3 grams of the moist precipitate was then made up with water to a thin paste, and allowed to remain at the ordinary temperature, loosely covered with a bell-glass. Watch glasses containing fresh blood serum and Koch's nutritive gelatine, served to control the experiments. The results of these experiments are shown in the following table :

Albuminates	Time after which the first Micro-organisms were observed. In days	Time after which putrefaction and bad smell were observed	Remarks
1. Serum	1	2	After the fourth day fungi appeared, which grew rapidly, covering the whole substance after ten days
2. Nutritive gelatine ..	1	4	
3. Phenol albumen serum	2	6	
4. Phenol albumen (white of egg)	2	6	
5. Copper albumen ..	28	40	
6. Zinc albuminate serum	31	46	After forty-six days the substance which had been light blue, changed and gave up the blue to the water. After thirty-one days fungi appeared, which covered the whole of the substance in fifty-four days
7. Zinc albuminate (white of egg) ..	31	46	After fifty-four days the substance assumed a dark colour and strongly putrid smell
8. Mercury albumen	42	60	Ditto
9. Mercury albumen (white of egg) ..	45	60	No fungoid growth
			Ditto

In a second series of trials the same metallic albuminates (prepared from blood serum) were sown with a green coccus found on an infusion of coffee. It consisted of cocci of an average diameter of 1.0 micro-millimetre, partly isolated and partly joined together in masses :

Albuminates	Time after which the sown fungus showed a distinct increase. In days	Remarks
1. Nutritive gelatine ..	2	Even after the lapse of four weeks it was not possible to detect either microscopically or microscopically an increase of the inoculated places
2. Copper albumen ..	No growth	
3. Zinc albuminate ..	"	
4. Mercury albumen ..	"	

In a third series of experiments splenetic-fever germs were dried on silk threads and brought into contact with the metallic albuminates.

Albuminate	Time at which the spores of splenetic-fever germs grew to threads. In days	Remarks
1. Nutritive gelatine..	I	Even after four weeks no growth of the spores was observable
2. Copper albumen ..	No growth	
3. Zinc albuminate ..	"	
4. Mercury albumen ..	"	

The same experiment was repeated with splenetic-fever bacilli. The latter rapidly shot out of the nutritive gelatine in threads which contained spores within the space of from three to four days. On the metallic albuminates, however, it was impossible to observe growth of any kind. From these experiments the following conclusions may be drawn:

1. The substances serving to control the first series of experiments exhibited fungoid growth in twenty-four hours, and showed distinct signs of putrefaction in from two to four days. The green micro-cocci, sown with nutritive gelatine, in the second series of trials increased perceptibly in two days, whilst the spores in the control substances of the third series of experiments had grown into threads.

2. The albumen precipitated by phenol, and subsequently washed, became putrid in the first series of experiments in forty-eight hours. This coincidence, remarkable on account of the permanency of the metallic albuminates, is explained in a simple manner. The coagulum of albumen produced by carbolic acid, when washed completely with water, was perfectly odourless, and on heating a large quantity of it with dilute sulphuric acid in a retort to the boiling-point, the distillate was perfectly free from phenol when tested with bromine. It is possible, therefore,

to completely wash out the phenol from the phenol albumen precipitate, and this explains why the phenol albumen, like the substances used to control the experiment, had become putrid.

3. The copper, zinc, and mercury albuminates proved to be unfavourable nutritive agents for micro-organisms. They would probably resist putrefaction for an unlimited period if they were not exposed to the action of atmospheric oxygen and water, by which action they appear to undergo gradual decomposition. It is an interesting fact that the antiseptic action of the inorganic metallic salts is the same as that of the corresponding albumen compounds. Mercuric chloride being the most powerful antiseptic albuminate of mercury also resists putrefaction for the longest period.

My experiments explain the differences of opinion which exist between the statements of those authors who consider chloride of zinc a valuable antiseptic and the experiments of Koch, according to which he fails to realize why chloride of zinc has ever received the name of a disinfectant. The metallic salts, when introduced into albuminous nutritive solutions or placed on wounds, immediately produce metallic albuminates, which compounds, although *per se* not poisons for germs, are no longer suitable for their nutrition, so that if *e.g.*, chloride of zinc is placed on the wound, or introduced into the nutritive solution in sufficient quantity to convert the whole of the albumen into zinc albuminate, the latter would resist decomposition by fungoid matter for a long time. Thus, *e.g.*, Amüat, in his experiments for preventing the putrefaction of pancreas, used, for 30 grams of the latter, 300 grams of a 1 per cent. solution of chloride of zinc. There is no doubt that the 3 grams of chloride of zinc employed were more than enough to coagulate the albumen contained in 30 grams of new glands. In order to test the action of chloride of zinc in arresting the development of germs, Koch made the following experiment. He added to 10 c.c. of the serum of blood a solution of chloride of zinc, so that the total liquid contained 1 per cent. of chloride of zinc; a second quantity of serum was treated so as to contain 5 per cent. of chloride of zinc in the total solution. Silk threads, with the spores of the splenic-fever organism, were then introduced into the solutions and examined under the microscope. After the lapse of twenty-four hours the spores contained in both vessels had grown to threads, their vegetation having been the same as that observed with the substances serving to control the tests. It is not stated whether the quantity of chloride of zinc employed was sufficient to precipitate the whole of the albumen and retain an excess of chloride of zinc in solution. If, however, as appears probable, the quantity of chloride of zinc was only large enough to throw down the whole of the albumen contained in the serum, the experiment has no meaning. The chloride of zinc is decomposed into hydrochloric acid and zinc albuminate, and it is easily conceivable that

the spores have grown to threads, having found enough nourishment in the unprecipitated portion of the albumen, and in the remainder of the constituents of the serum. From a similar reason corrosive sublimate, which, according to the researches of Buchholtz, surpasses all other antiseptics when added to solutions of albumen, is converted into mercury albuminate, and no longer possesses the same antiseptic properties which characterize chloride of mercury. Koch injected 1 gram of a 1 per cent. solution of corrosive sublimate into a Guinea-pig, and inoculated it on the same day with splenetic-fever bacilli. The next day the inoculated places were much reddened and swollen. The Guinea-pig then received, on the morning of the second day, 2 grams of the same solution of corrosive sublimate. According to Koch's estimation, this quantity would be sufficient to prevent the growth of bacilli in a nutritive solution equal in weight to the whole body of the animal experimented with. The animal nevertheless died, during the following night, from splenetic fever. The explanation of this is very simple. The 3 milligrams of corrosive sublimate injected into the pig were sufficient to convert only a small portion of the soluble albumen into mercury albuminate. As the latter is readily soluble in an excess of albumen, and also in solutions of common salt, and is not a direct poison for micro-organisms, the injected solution of corrosive sublimate could not exercise any influence over the inoculated splenetic-fever bacilli.

In the course of my investigations I have tested the antiseptic action of another antiseptic agent, the use of which for surgical purposes, although considerable at first, has been abandoned, viz., iodoform and the chemical compounds related thereto. As the pancreas and the liver of animals contain large quantities of micro-organisms, and the soluble ferments contained in the glands of the stomach promote putrefaction, I used the pancreas of oxen, as being the most reliable criterion of testing these substances for their capability of arresting the development of germs. 20 grams of pancreas and 2 grams of iodoform were added to 100 grams of water; the mixture was well shaken, and allowed to stand at a temperature of from 35° to 38° Centigrade. The whole had a strong odour of iodoform. After twenty-four hours' standing the pancreas became putrid, as though it had been in pure water. The experiment was then repeated with the following modification: 10 grams of perfectly fresh pancreas was intimately mixed with 2 grams of iodoform, and treated with enough water to cover it and prevent it from drying. The temperature was 35° to 38° Centigrade. After the lapse of twenty-four hours this mixture became as putrid as the first. As, according to the opinions of most experimentalists, iodoform, when applied to wounds, acts as an antiseptic, inasmuch as it is gradually decomposed with the liberation of iodine, and the latter is the real active agent, I tried to replace the iodoform by

carbon tetraiodide, C I_4 , a substance prepared a few years ago by Gustavson. Its preparation in a pure form and on a large scale was, however, very troublesome. I have, on the other hand, examined the antiseptic action of the three carbon chlorides, viz. carbon dichloride (C_2Cl_4), carbon hexachloride (C_2Cl_6), and carbon tetrachloride (CCl_4). Experiments were made also with the two bromotoluenes—the solid and liquid—with pyrogalloldimethylether and paracresol. The results, which are illustrated in the subjoined table, show that cresol only arrests the development of fungoid germs, its action being equal to that of phenol. The other substances, which were used in the proportion of 1 to 100 of water, were perfectly inactive. In these experiments 20 grams of pancreas were treated with 100 grams of water, and digested with the substance under examination at 35° to 38° Centigrade.

Name of substance	Percentage of the solution	Time after which Putrefaction sets in. In days	Remarks
Carbon dichloride C_2Cl_4	1.0	1	
Carbon hexachloride C_2Cl_6	1.0	1	
Carbon tetrachloride CCl_4	1.0	1	
Bromotoluene (solid)	1.0	1	
Bromotoluene (liquid)	1.0	1	
Pyrogalloldimethylether	1.0	1	
Paracresol ..	0.05	1	
" ..	0.1	1	
" ..	0.2	1	
" ..	0.3	1	
" ..	0.4	1	A few threads were developed having a slightly putrid odour
" ..	0.5	No putrescence	Even after eight days not the slightest trace of putrefaction is noticeable.
" ..	1.0	..	Large masses of tyrosin crystals were formed, which is a proof of the fact that the action of the soluble ferments on the pancreas has not been arrested.
" ..	2.0	..	

Laboratory of Prof. Nencki in Bern.

